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AUDITORY PERCEPTION IN INSECTS, WITH SPECIAL REFERENCE TO THE COCKROACH

By PHIL RAU

Kirkwood, Missouri

DO INSECTS HEAR?

MANY insect species of various orders are capable of giving forth sounds. These sounds differ greatly in their nature, and are produced by various activities and by the use of manifold mechanical devices of the body.

Some of these insects that create sounds have organs which, from morphological and experimental investigation, are generally considered to be organs of hearing; there are other sound-producing insects upon whose bodies no organs of hearing have been found. Yet other species of insects are considered dumb because they have no organs of hearing and also are unable to create sounds, at least such as can be perceived by the human ear. There are still other insects that are known to possess organs of sound perception, even though they themselves create no sounds audible to the human ear. It seems logical to assume that sound-perception should be the complement of sound-production, or at least to expect that the functions of voluntary sound-production and of sound-reception will exist together and not separately.

A survey of the literature of these two phases of the subject reveals the startling fact that the references on sound-production out-number those on sound-perception by at least twenty to one. The reason for this is that it is far easier to describe what an insect does and how it behaves than to tell how it feels and what it perceives. The result is that all present-day naturalists agree that some insects are capable of making sounds, but not all of them will agree that insects actually hear sounds that they or others create. It is now about fifty years since the subject of auditory perception in insects came into prominence. Students have been prone to decline to attribute this ability to insects, sometimes even in the face of the evidence from excellent experimental work, and some of the writers go so far as to refuse to concede hearing even in those insects which possess well-developed tympanal organs, and have no patience with even

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the hypothesis that the so-called "dumb" insects—those in which neither stridulating nor hearing organs have yet been discovered—may have the ability to respond to sound-vibrations.

One might well think it logical to suspect, when a male cricket sings and the female comes to him, that she is attracted by his song. The criticism generally is that the experimenter has not absolutely ruled out the senses of sight and smell. One would also think that when an insect responds to sounds artificially created, it reacts to them by the sense of hearing. But the objection here again is that they may have been influenced by tactile stimulation. The work on the hearing of insects which has been done in the last twenty years has to a large extent mastered these criticisms, yet we often come upon statements which indicate that the newer work has been overlooked.

Lutz (1924) questions whether the sounds produced by insects have any more purpose than the snoring of a man when asleep, or the rattling of an automobile. He says (p. 333),

> "insect sounds are not made for the purpose of being heard by human ears. Whether the insects themselves hear these sounds is the important question and one that has not been—possibly cannot be—determined beyond all doubt." Again (p. 367), "I am not aware of a single experiment that has furnished indisputable evidence of communication between insects by means of sound."

Washburn (1926) is likewise parsimonious in giving insects credit for sound perception. There are three editions of her ever popular book, *The Animal Mind*, and the opening sentence in her chapter on the hearing of insects is the same in all of them. "The sense of hearing in insects is also problematical." In spite of much new data published during the nineteen years that have elapsed between the first and the third editions, the space devoted to this topic has increased to the extent of only one page.

As late as 1934, we find in the college text by Warden, Jenkins and Warner, entitled *Introduction to Comparative Psychology*, this statement (p. 144):

> "Many of the insects possess chordotonal organs in both the larval and the adult stages, and these are commonly regarded as phonoreceptors. In most cases, however, these organs are very simple, and it appears unlikely that they serve auditory functions. The behavioral evidence . . . is against the view that the simple types of chordotonal organs are phonoreceptors." They take exception to this, in a reserved way, when they continue, "The only positive evidence for hearing in insects that is entirely trustworthy is that relating to crickets, grasshoppers, katydids, locusts and related forms, which are known to possess highly complex chordotonal organs. It is interesting to note that these forms are also stridulating types."

Since much diversity of evidence and opinion exists in this field, I have attempted to bring together a survey of the literature on this subject.

One may hardly speak of hearing in insects without touching upon the still larger subject of the organs for the perception of sound. References to the organs of hearing in insects I have omitted from this discussion. A comprehensive review can be had in Chapter 6 of Imms' *Recent Advances in Entomology* (1931). Likewise the literature on sound production in insects, which is a large one indeed, has also been for the most part omitted. Only those works are included which contain material on sound perception as well as sound production. Even all references to works which support sound-perception on morphological grounds only have been omitted. If an insect possesses tympanal or chordotonal organs, it seems quite likely that it hears sounds; this alone, however, is insufficient proof, in my opinion. The work, to be included in this review, must also cover observa-

tional or experimental data to show whether or not the insects hear sounds.

Ants

Most species of ants produce no sound that is audible to the human ear, although Emery (1893) reports certain East Indian species that make a loud, hissing noise when disturbed, and some species are said to chirp.

Janet (1893 and 1894) maintains that ants of the Myrmicidae make stridulating noises. Forel (1930, p. 215), says, "as far as I know there is only one ant, *Megalaponera foetens* of Africa, which stridulates in a fashion that is clearly perceptible to our ears, but many of the Ponerinae and Myrmicinae have stridulating organs." None of these three investigators has experimented to learn whether or not these stridulations are heard by other members of the colony. Wheeler (1910, pp. 512–514), however, not only shows that the stridulatory organs are well developed in the Ponerinae, Myrmicinae, and in a rudimental form in the Dorylinae, and that the ants possessing these organs emit very shrill sounds, usually of so high a pitch as to be inaudible to us, but that these sounds are means of communication ignored by many authors. In contradiction to the view of Forel and others who deny hearing in ants, "several authors (Metcalf, Weld and Wasmann)," writes Wheeler, "have recently maintained that ants do perceive aerial vibrations." Wheeler himself at one time took this stand when, on actually watching the sound producing proclivities of ants, he says (1903),

"I have also virulently expressed myself in favor of such a view." "Stridulation readily explains the rapid congregation of ants (Myrmicinae) on any particle of food which one of their number has found, for the excitement of finding food almost always causes an ant to stridulate and this attracts other ants in the vicinity. It also explains the rapid spread of a desire to defend the colony when the nest is disturbed. This is especially noticeable in species of *Pheidole myrmica* and *Pogonomyrmex*. It is the secret of being able in a short time to catch ants like *P. molefaciens* in great numbers by simply burying a wide-mouthed bottle up to its neck in the mound of the nest."

The stridulation of one or two ants that fall in at once attracts other ants which hurry over the rim and "forthwith swell the stridulating chorus till it is audible even to the human ear." If the bottle be corked and shaken for the purpose of still further exciting the contents, and then held over another *Pogonomyrmex* colony whose members are peacefully sauntering about on the dome of the nest, "the wildest excitement will suddenly prevail, as if there had been a call to arms —or to dinner." Wheeler, in describing the stridulation of the Texas leaf-cutting ant, *Atta fervens* (= *texana*), says,

"Even more remarkable is the stridulation" in a colony of these ants. "Here the different ants, from the huge females through the males, large soldiers and diminishing castes of workers to the tiny minims, present a sliding scale of audibility. The rasping stridulation of the queen can be heard when the insect is held a foot or more from the ear. To be audible the male and the soldier must be held somewhat closer, the largest workers still closer, whereas the smallest workers and minims, though stridulation may be seen from the movements of the gaster on the post-petiole, are quite inaudible to the human ear." He goes on to say that it is not at all improbable that "all this differentiation in pitch, correlated as it is with a differentiation in the size and functions of the various members of the colony, is a very important factor in the cooperation of these insects and ants in general. The contact odor sense, important as it undoubtedly is, must obviously have its limitations in the dark subterranean cavities in which the ants spend so much of their time, especially when the nests are very extensive like those of *Atta*."

At one time Wheeler believed that ants not only can hear, but that they communicate by means of sounds; but after the appearance of a paper by Fielde and

Parker (see paragraph below), he asserts that there is not sufficient evidence to warrant the assumption that ants can hear. However, he fully realized the importance of his observations on the reactions of ants to sounds made by other ants, for he says that if the views of Miss Fielde and Parker be accepted, we must suppose that *Pogonomyrmex* were thrown into agitation by vibrations passing from the bottle of stridulating ants, through his body, to the soil of the nest. At first it seemed more probable that the ants perceived the stridulation directly as aerial vibrations. However, despite the supporting evidence by Turner, Wheeler became influenced by this work and cast a note of doubt over the entire subject by finally saying it is extremely difficult to exclude the transfer to the ants of vibrations through the floor, table and walls of the nest, "and for this reason we cannot with the data at hand reject the statements of Fielde and Parker," and we shall be more within the bounds of accuracy "if we discuss the question from the standpoint of mechanical stimulation, rather than to set up questionable distinctions based upon human sensations." Thus he acquiesces, where he might well have stood his ground, on the basis that the sounds and reactions by the insects themselves in his field observations are a better test of their hearing ability than experiments in the laboratory.

It is interesting to note, in passing, the attitude of Sir John Lubbock (1929, p. 168), in the face of far more discouraging results than Wheeler's. After experimenting on the hearing of ants, bees and wasps with the loudest and shrillest noises that he could produce, and getting only negative results, he still believed that ants could hear, for he says, "On the whole, although the subject is still involved in doubt, I am disposed to think that ants perceive sounds which we cannot hear."

And now to consider the work of Fielde and Parker (1904). They could not get any reactions from ants to aerial sound waves from a piano, Galton whistle and violin, which collectively gave a range of from 27 to 60,000 vibrations per second. The ants reacted, however, to vibrations reaching them through the soil and other solids. These vibrations were received through the legs, as they were perceived even when the antennae, head, abdomen and any one or two legs were removed.

Turner (1907) found that when ants are outside the nest they pay little or no attention to sounds, but when inside they respond to them with very active movements. This is true even when precaution is taken to prevent the sound waves from reaching them through any medium other than air. Turner's work was carefully planned with reference to eliminating tactile perception, and the results show that *Formica fusca* and *F. sanguinea* are sensitive to vibrations of the air "which to human ears would be sounds." These two species are not known to stridulate, but they respond to vibrations as low as 256 and as high as 4138 per second.

The responses were in the form of zig-zag movements, and were usually slight for pitches higher than 3000 vibrations per second, and sometimes to other pitches; but to most pitches under 3000 vibrations per second the ants usually responded in a pronounced manner, usually darting about as though much excited.

Wasmann (1891) has noted reactions of ants to sounds, and, like Turner, worked with them within the nests. Washburn (1926) thinks he was not careful to exclude the possibility of vibrations other than sound waves influencing their behavior, but if a translation by Staeger (1928) reviewing the work is correct, Wasmann's work and method are legit-

imate. He experimented on a colony of "forest ants" in an artificial nest. Such a nest consists of a rectangular block of wood or plaster, closed on top with a glass plate. In this case the glass had been accidentally cracked, and he closed the crack with shellac. When the laquer was entirely dry, he passed a steel needle lightly across it, whereupon the ants in the nest suddenly stretched out their antennae, agitated them and tried to touch the glass above them by raising the fore part of the body. The movement was so sudden and general that he repeated the test several times, always with the same result. But if he rubbed the same place with some smooth object, as a paper knife, the ants paid little attention. As soon as he again scratched the shellac with the needle, thus evoking an extremely fine, high-pitched stridulation, the movement described above was repeated; this, he concluded, was reaction to sound waves. The fact that the ants reacted only to this high-pitched, fine sound may indicate that it resembled something of biological importance to them, probably of a friendly nature, since they reached for it instead of fleeing from it. If their movement was due to a shaking of the nest, it would also have happened when a paper-knife or other object was used. In the light of work done on hearing among other insects, we can appreciate Wasmann's work today better than when it was done nearly fifty years ago.

Weld (1899) has experimented on *Crematogaster lineolata*, *Lasius americanus* and *Aphaenogaster* sp., and Metcalf (1900) on a small black ant, to the conclusion that ants perceive aerial vibrations.

Eltringham (1933, p. 75), says that Baier experimented with the ant *Myrmica rubida* and obtained responses to some notes on a violin.

Lubbock (1929, p. 168), says that St. Fargeau attributed the power of hearing in ants, as well as to bees and wasps.

In contrast to the foregoing reviews of the works of investigators who are inclined to credit ants with the sense of hearing, we have a host of students who protest against it, some of them almost vehemently. Some of them do so on grounds of observation and experiment, some on morphological grounds, and some merely on theory.

Huber (1820) says that ants are quite deaf, but offers no experimental proof.

Lubbock (1929) likewise found that *Camponotus ligniperdus* took no notice of any sound which he was able to produce. Likewise the tests on *Lasius*, in which he wished to find if possible whether ants have the power of summoning one another by sound, he could not find any communication transmitted. Even after this he remained skeptical, and maintained that ants, "even if deaf to the sounds we hear, may hear others to which we are deaf."

Forel stood firm throughout his long life in refusing to credit insects with the sense of hearing. In his early work, probably done in the 1880's and brought together in Forel (1908, pp. 109–110), he concludes:

> "What may be considered as proof of hearing appears to me to rest, with a few exceptions, almost certainly upon mechanical vibrations of the air or ground. These are simply perceived as such by the tactile organs of insects, . . . but it is not right to call such sensations hearing." In a work appearing just a few years before his death, Forel (1930, pp. 215–219) says, "Apart from crickets, some locusts and grasshoppers, the other insects appear to remain deaf as soon as we eliminate the mechanical shocks to which all of them are highly sensitive. I have shouted and whistled with all the force of my lungs equally close to various insects while protecting them from my breath. So long as they did not see me, they paid no attention." "We can hardly give much credence to Leon Dufour, who thought he had proved hearing in crickets because they ceased their

chirping when he struck the ground with his foot. . . . He forgot that the deaf and dumb feel the rumbling of a carriage at a distance." "Sound waves, especially those of low-pitched sounds, bear a much closer resemblance to powerful mechanical shocks than luminous caloric or electrical waves. Hearing has therefore a fundamental connection with touch." "All these facts, so it seems to me, combine to show that if insects, particularly ants, have any hearing, it takes place in some way different from our own, even in crickets and locusts. We are justified in assuming that they perceive the stridulations of their species as shocks at a certain distance." And finally, waxing a bit facetious, "This is all we know about the ants' sense of hearing. You will admit, dear Reader, that it is very scanty, and will be prepared to exclaim, as I did, when I had refuted the long dissertations of so many authors on the seat of insect hearing: 'Heavens! What a large number of ears for such a deaf folk!' "

Myers (see Lubbock, 1929, p. 331), says Forel has long lent the weight of his authority as entomologist and psychologist to the opinion that not only ants, but insects in general, are deaf.

It is true that many experiments clearly indicate in insects an entire unconcern with vibrations which seem very loud noises to us; it is probable also that their very small size and nature of their framework—a rigid exoskeleton—make them sensitive to vibrations imperceptible to us, which they perceive by other means than hearing in the strict sense of the term. There is, however, considerable experimental evidence that insects can hear, and there are on the one hand complicated structures devoted exclusively to the production of special sounds, and on the other hand exceedingly complex organs to which it is difficult to assign any other function than that of hearing.

Bees

Lubbock (1929) failed to get hive bees to respond to artificial sounds. Bethe (1900) and Forel (1888) believed bees to be deaf. Armbruster (1914, 1922) reports that bees do not hear the sounds that they make, and experiments by Kröning (1925) show that bees do not hear artificial sounds of the same pitch range as their own. McIndoo (1922) is skeptical about hearing in bees, because their only possible auditory organs, the chordotonal, lack the external tympanum present in crickets and katydids. In his conclusion, despite the fact that he has added nothing experimentally or observationally on sound perception, he expresses agreement with Forel's interpretation.

Despite these dissenting notes, one can hardly laugh off the observations of Buttel-Reepen (1907), a keen observer of bees. He says odor is not the only factor in communication among bees, for when the colony notes the absence of the queen, there is always a change in the usual characteristic sound in the hive. There is therefore

not the slightest doubt in my mind that bees communicate with each other by sound. The tone of peace attracts hive mates or quiets them; the louder buzzing excites them; it disappears if the queen is given back. At the same time the whole character of the colony changes, and queenless, irritable bees become quiet and peaceful and again take up their life work, which was laid aside during the excitement. We must admit the possibility of communication between bees by sound, therefore of hearing capacity and sound sensations. Each bee has the instinct to join in the tone of discontent if it hears it; therefore if the absence of the queen is noticed by one bee, the agitation is very quickly propagated throughout the colony.

Mrs. Comstock (see Lutz, 1924), in her *How to Keep Bees*, says,

The belligerent attitude of the queens toward each other seems to have been so strong an emotion that a voice has been developed to express it. This note must be heard to be understood; as nearly as I am able to spell it, it is 'tse-ep, tse-e-e-ep, tse-e-ep, tsep, tsp, tsp, ts', in a sort of diminuendo. She makes this noise when she discovers another queen cell; if there is within this cell a full-fledged queen, she pipes back, but it sounds quite different, and is more like 'quack, quack'. This piping of the queen is especially evident before an after-swarm is to issue. The queen will also pipe when the bees gather about and try to ball her. In this case the note is one of righteous anger. Her wings vibrate tremendously

while she is piping, but she can pipe quite vociferously after her wings have been entirely cut off.

Cheshire (see Lutz, 1924) cannot but regard the negative results of Lubbock's observations as inconclusive, since "tuning-forks, whistles and violins emit no sound to which any instinct of these creatures would respond." Should some alien watch humanity during a thunder storm he might quite similarly decide that thunder to us was inaudible.

"Clap might follow after clap without securing any external sign of recognition; yet let a little child with a tiny voice but shriek for help, and all would at once be awakened to activity." "In practical matters, the hearing of bees is not only often obvious, but must be taken into account—e.g., when a swarm is about to be transferred to its permanent abode from its temporary one, many will stick to the sides of the latter after the bulk have been thrown out, and these, by their buzz, will distract those that are running in at the new hive door. The removal of the stragglers to a distance will end the disturbance; which will be renewed if they be returned to their former position."

He relates another significant incident, witnessed by several people. Where several swarms of bees were being handled, nearly a pint of lost bees had collected for mutual comfort on a piece of damp canvas at the bottom of a tent-pole. No sooner did the bees in the skep on the table above set up the well-known roar than those on the canvas, hitherto so very quiet, faced about and unhesitantingly went up the pole and settled on the outside of the skep. He concludes: "This circumstance I remember as offering to all who witnessed it conclusive evidence of hearing. Piping queens, whatever be the cause, seem to point to a sense of hearing, for it appears to be a sound made for an object and not the result of some necessary movement."

Wasps

The Peckhams (1887) carried on some experiments on the hearing of the social paper-making yellow-jackets, *Vespa germanica*, and obtained negative results. They stood one foot away from the nest at a time when the wasps were entering rapidly (two hundred in five minutes), and made several kinds of noises, shouting, whistling and clapping of hands, but the wasps took no notice. We should not forget that probably these sounds had no life significance for them.

Latoste (1929) offers experiments to show that *Vespa crabro* is not deaf, although it may not react to sounds when exhausted or when subjected to repeated stimulus.

In Panama there is a social wasp, *Synoeca surinama* (Rau, 1933, pp. 122–123) with a severe barbed sting. When danger threatens, these wasps send out a musical warning before launching an attack. The use of the barbed sting means the death of the wasp; I believe this is why they are reticent about attacking an intruder without first trying to frighten him away with their noise. The combs of the nest, fastened vertically against the tree-trunk, have a covering of heavy, corrugated cardboard which serves as a sounding-board when the inmates beat their wings against the inner surface of it. Thus they have built up an elaborate and effective defense mechanism on the use of sound, but I can offer no experimental proof that they themselves hear these sounds which they cooperatively produce.

For the social wasp, *Polistes pallipes*, Rau (1939) found that when sound waves of 2000 vibrations and 6000 vibrations per second were continuously focused on workers while they were asleep, their "abdomens pulsated rhythmically while simultaneously the sting moved in and out." The wasps responded thus, apparently, without waking.

Ormerod (1868), p. 74, is quite certain that the British social wasps not only do

hear, but that they also "make certain noises with the intention of being heard."

Lutz (1924, p. 361), says of the cicada hunting wasp, *Sphecius speciosus*, that since she catches about as many female cicadas as she does males, it indicates that she does not hear the sounds produced by the males.

Termites

Andrews (1911) has conducted experiments which, he thinks, indicate that termites respond to concussions of air as such. The noise of thunder and the blasting of rocks would send thousands of them scurrying to their nest. Even the clapping of hands, which probably was too light to jar the stone upon which the nest rested, would produce the same effect. He interprets this, not as a case of audition, but merely that termites seem to respond to certain concussions of air.

Emerson (1928) reports that certain sounds by termites have often been heard, and it is also well known that the termites possess so-called ears on the tibiae. In *Nasutitermes guyanae*, he finds soldiers and workers made no response to any noises he made, even when only six inches away from them; however, when he touched the nest, even delicately, "the excited response was very definite." He has heard sounds produced by workers of *Armitermes percutiens* when the colony was disturbed, and he thinks these probably are of use "as a warning to other members of the colony." These sounds are audible to human ears even five or six feet away. With an apparatus especially constructed for the purpose, Emerson tested the substratum vibrations of *Reticulitermes flavipes*. Some of the soldiers resting on the wood were disturbed and were thus stimulated to hammer their heads upon the substratum. The noise was so great that it sounded unpleasantly loud through the ear phones. "Thus it can be seen that termites in widely separated groups have the power to transmit substratum vibrations, and the experiments indicate that they have the power to hear vibrations through the substratum."

Beetles

Of the death-watch beetle, which produces sound by tapping with its head or abdomen, Lubbock (1888, p. 66), says, "if a male death-watch ticks and there is a female within several yards, she returns the tap and they approach one another slowly, tapping at intervals until they meet."

Tower (1906) observed the potato beetle reacting to the sound of a tuning-fork. He says, p. 225, "if a slight noise be made, the insect will pause, if the noise be continued, they seek safety in flight and if it is greatly increased, they assume the so-called death attitude."

Will (1885) mentions his experiment on the beetle *Cerambyx scopuli*. He enclosed a female in a box, and at intervals irritated her with a pin and caused her to stridulate. The male, six inches away, would at these time grow restless and move toward the box.

Darwin (1894), in discussing stridulation in beetles, cites several instances where the males stridulate "in order to call or to excite the females." Beetles stridulate under various emotions; some stridulate "in anger or defence," others "from distress or fear," "to encourage the female in her work," "to frighten enemies," and finally, "it is probable that the two sexes of many kinds of beetles were first enabled to find each other by the slight shuffling noise produced by the rubbing together of the adjoining hard parts of their bodies," but not in one

instance does he prove that these sounds were heard by the insects themselves.

Bugs

The back-swimmers, *Buenoa limnocastris*, began to chirp almost as soon as Hungerford (1934) brought them into the laboratory; even in the obscure light of the pail, he says, it was apparent that the females inspired the singing.

> They sang their courtship songs at all hours of the day or night, on cloudy days, on clear days, in sunshine or shadow. In the aquarium containing three pairs there were times when all the males were singing at once. . . . The male singles out a female, maneuvers for a position some distance beneath and behind her, and begins a ticking sound as he slowly cruises nearer the object of his desire, his body aquiver with emotion. When within a half-inch or so of the female, the ticking changes to a hum, and is followed by a sudden dash to embrace her.

For the water-strider, *Gerris remiges*, Essenberg (1915) finds that when a door is slammed or a metallic sound is made, these insects immediately respond by darting backward. If buzzing insects are dropped into the water, the striders rush toward them, but if the proffered insects are dead, they make no response. These experiments were tried also with blinded *Gerris* with the same results, the sightless striders moving from all directions toward the source of sound. These facts induced Essenberg to believe that water-striders can hear.

Graber (1882) found that a water insect, *Corixa*, was undisturbed by a bone disc being pushed toward it in the water, but gave decided reactions when the disc was connected with an electric bell.

Graber (see Lubbock, 1888, p. 75) also made some ingenious experiments on the water-boatman, *Corixa*. He placed them in a deep jar of water at the bottom of which was a layer of mud. He dropped in stones which sank in the mud, but the beetles, reposing on some weeds, took no notice. He then placed a piece of glass on top of the mud and dropped in stones as before, thus making a noise, although the disturbance of the water was the same as before. The water-boatmen than took flight.

Book lice

Pearman (1929) says that sound production by *Clothilla pulsatoria* has long been known. The female taps with its abdomen at the rate of five or six a second. "The sounds produced are undoubtedly the mating calls of the female."

Flies

Hancock (1911, p. 215), says some male Tabanus flies have been able to win females by their humming sound. Müller has seen an Eristalis courting a female by hovering above her and flying from side to side, making at the same time a high, humming sound.

The striking work of Mayer (1874) on adult mosquitoes frequently appears in discussions of the hearing of insects. He fastened a live male mosquito to a glass slide, and had a series of tuning forks of different pitch sounded.

> When the Ut_4 fork of 512 vibrations per second was sounded, many of the antennal hairs were set, sympathetically, in strong vibration. Tuning forks of a pitch an octave lower and an octave higher also caused more vibrations than any intermediate notes. The male mosquito's auditory hairs are specially fitted to respond to, i.e., be stimulated by notes of a pitch produced by 512 vibrations. Those auditory hairs are most affected which are at right angles to the direction from which the sound comes. From this it is obvious that, from the position of the antennae and the hairs, a sound will be loudest or most intense if it is directly in front of the head. If the mosquito is attracted by sound, it will thus be brought straight head on toward the source of the sound. As a matter of fact, Mayer found the female mosquito's song to correspond nearly to Ut_4, and that her song set the male's auditory hairs into vibration.

With little doubt, comments Kellogg (1905) the male mosquitoes find the females by their sense of hearing.

Cicadas

Fabre's experiments (1919) on hearing in the cicada is often cited by those who wish to discredit sound perception in insects. A half-dozen cicadas refused to stop their singing when he fired off thunderous explosions of gunpowder from two cannon which he had borrowed from the municipal artillery and placed under the tree. With a flourish he says, "The mighty explosion has in no way affected the song of the cicadae," and concludes that they are "extremely hard of hearing, and we may apply to him the familiar saying, 'to bawl like a deaf man'." Fabre forgets for the moment that those sounds have no significance to them, as the noise of a bird, a lizard or any natural enemy of cicadas might have had. Fabre lapses into another of his frequent paradoxes when he says in the same breath, "I see in the grasshopper's fiddle, the frog's bagpipes, and the cymbals of the Cacan, but so many methods of expressing the joy of living." But how could sounds purposely made, produce joy unless by being heard?

Myers (1929, p. 200) and Myers and Myers (1928), after much careful observation of a number of cicada species in different parts of the world, say that "we may legitimately conclude that cicadas hear."

Imms (1931, p. 125) remarks that in the Cicadidae the presumed absence of any receptor organs for sound vibrations had for many years been the outstanding difficulty in interpreting the function of highly developed powers of sound production. It was not until 1923 that Vogel in Germany proved by histological studies that true tympanal organs are present in both sexes.

Richards (1927) cites Poulton's (1896) observation that the males of the cicada *Monometopa insignis* call in rivalry in close proximity to the females. In this species also there was evidence that the sound had to be made for some time before the females became acquiescent. On one occasion the male attempted to copulate too soon, and was unsuccessful; he moved back to his original position and continued singing to the female who remained by him.

Another conspicuous bit of proof that cicadas perceive sounds is an article by Marlatt (1898), wherein he says that *Cicada septendecim* is heard between the hours of 11 and 3, but never between sunset and sunrise. However, on rare occasions when disturbed, they will start up singing in concert in the middle of the night. He quotes Prof. A. D. Hopkins, who noted an instance of this in West Virginia:

> I was fortunate to hear the starting of one of these concerts on a clear, moonlight night in June. One male in an apple tree suddenly called out as if disturbed or frightened. His neighbors in the same tree were apparently awakened. One started the familiar song note which was at once taken up by numbers of other males, and, like the waves of a pebble dropped into still water, the music rapidly spread until it reached the edge of the thick woods, where it was taken up by thousands of singers, and the concert was in full blast as it had been the previous day. This continued for a few minutes until all had apparently taken part and the song had reached its highest pitch, when it began to gradually subside, and in a short time silence again prevailed.

Moths and butterflies

Snodgrass (1928) mentions that Peter has recorded evidence of perception of sound by a female moth, *Endrosa remosa*. The males of the species, he says, make a cracking sound as they fly, and when one comes near a female sitting quietly

and hidden in her usual manner, she bestirs herself with a trembling and fluttering motion as long as the male continues his sound-making. After mating the females no longer respond to the sounds of the males.

Snodgrass also cites Eggers' (1925) experiments on Noctuid moths, *Agrostis pronuba*. These moths possess tympanal chordotonal organs on the base of the thorax, and respond to loud sounds, especially to the sharp, squeaking noise made by the turning of a glass stopper in the neck of a bottle. They react to the sound with a movement of fright, starting to fly or to run, but on the cessation of the sound they fall back into the position of repose. Destroying one tympanum and its chordotonal organ has no effect on the reaction, but if the organs on both sides of the body are destroyed the moths will no longer react to sounds.

Turner (1914) and Turner and Schwarz (1914) have done excellent experimental work on the hearing of Saturniid moths in the laboratory, and on Catocala moths in the open field. These moths are not known to make sounds. Turner finds that of four species of silk-worm moths, three respond readily to a large range of sounds, and the fourth, *Telea polyphemus*, normally does not. By causing *polyphemus* to associate punishment with certain sounds it can be induced to respond to those sounds. In their outdoor tests with Catocala moths, they found several different species to respond to high notes, either by flying or by quivering the wings. By touching the insect at the moment when the whistle-tone was sounded, thus giving to the sound a life-significance, they trained some of the moths to react to a lower organ tone. These authors conclude: "It seems certain that all four species of Saturniid moths and several species of Catocala moths can hear." "The fact that an insect does not respond to a sound is no sign that it does not hear it. The response depends upon whether or no the sound has life significance."

Heinrich (1909) remarks that he noticed a *Laurentia suffumanta* alight in a concert pavilion and remain quietly at rest while the brass band played three numbers, one of which was Wagner's Götterdämmerung. He also observed that certain Lepidoptera were more easily approached at twilight than when the sun was shining brightly, and he could not understand why this should be true if they were warned by a sense of hearing. He is convinced in all of these cases, that it is vision, not audition, that warns the butterflies and moths of danger.

Hamann (1909) was led to investigate the subject by the remarks of collectors that butterflies and moths undoubtedly hear. One man said that the noise caused by removing the cork from the cyanide bottle often caused the insects to fly away; to this Hamann replied that the net is usually placed beneath the insect at that time, and the sight of that may cause the insect's flight. To test the matter, he approached a tree in such a manner as to be invisible to an *Apatura iris* that was resting on it, and struck the tree with the bamboo handle of his net. To this the insect made no response, but as soon as the net approached it took flight. A repetition of the experiment with *Vanessa* yielded similar results. He also noticed that Catocalas which were not disturbed by the noise of a passing automobile flew upon the approach of man. These tests convinced him that butterflies and moths cannot hear.

Rothke (1909) thinks that butterflies and moths can hear sounds.

Richter (1909) made observations upon *Catocala pacta*, and is convinced that the crackling of twigs underfoot, and even

the slight noise made by removing the cork from his collecting bottle, disturbed the moth. In another article (1910), he made a comparative study of the auditory powers of the day-flying and night-flying Lepidoptera. *Limenitis populi* and *Sat. alcyone*, and species of *Apatura* and *Vanessa* made no response to sound so long as no visible object disturbed them. During a severe storm he noticed a number of *Sat. alcyone* perching on a limb. Neither whistling, the clapping of hands nor the shaking of the limb disturbed them, but as soon as the hand of the collector approached, they flew. A *Vanessa antipoda* was not disturbed by the shrill whistle and rumbling noise of a passing train. A night-flying *Catocala fraxini* made no response to the noises made by wagons, automobiles and bells of the ferry, but it responded readily to slight, high-pitched sounds. He suggests that the sounds to which they react are similar to those made by field-mice, bats and owls—sounds which for the moth have pronounced life significance. Richter is convinced that day-flying Lepidoptera are warned by visual, and night-flying forms by auditory, stimuli.

Collenette (1928) records an *Ageronia* responding to a noise made by birds. He noticed two small warblers fighting on the ground, and heard one bird frequently making a rapid, clicking sound with its beak. A butterfly, *Ageronia feeda sabatia*, lighted on his coat, and each time the birds made the clicking noise the butterfly took a short turn in the air, and gave its characteristic clicking noise in reply. The sounds made by the bird and the butterfly were very similar, both in quality and speed of utterance. "The prompt response of the insect left no doubt that it was replying to the birds."

Eltringham (1933, p. 76) after reviewing the subject of hearing in insects, including many Lepitoptera, concludes that there is little evidence that insects (other than grasshoppers and cicadas) can hear in a sense comparable with that faculty in the vertebrates.

> They may be and sometimes are affected by sounds and respond to them, but in the majority of observed cases the action is probably more akin to a tactile sense of vibration than to a true auditory sense. It may even be a sympathetic vibration in response to air waves of a certain frequency just as a glass bowl or string of a muscial instrument "will respond to air-borne waves of a frequency similar to that of their own natural periods."

I may say, parenthetically, that these conclusions are based on a study of insufficient literature; many important references (such as Turner, 1914) have been omitted which might have modified the complexion of the deductions.

Caterpillars

Minnich (1925), according to Eltringham (1933), experimented with the larvae of the butterfly, *Vanessa antipoda*. In response to sounds, they moved the anterior part of the body. They were affected by the human voice, a piano, organ, violin and tuning forks; pitches of 32 to 1024 were effective. As decapitated bodies and parts of bodies also responded, he concluded that the organs involved were certain hairs on the anterior part of the body.

Baier's experiments (1930) with larvae of the cabbage butterfly, *Pieris brassicae*, confirm these results.

Abbott (1927) carried on similar tests on caterpillars of the moth *Datana perspicua*. Definite responses were noted to air currents, sudden jars, and only two notes, C″ (512 vibrations per second) and F sharp (728 vibrations). Larvae thus stimulated elevated the anterior and posterior regions of the body. During the experiments the larvae were protected

from air currents; they were several feet from the instruments, and vibrations from the substratum were eliminated. The caterpillars showed no response when the body hairs were covered with water, or when the body surface was anaesthetized with a 2 per cent solution of procain.

Minnich (1936) tested seven species of butterfly larvae and eight species of moth larvae, belonging to eight different families, and has found them to be responsive to sound. The response to sound of hairless forms he finds to be essentially the same as for the very hairy forms.

Short-antennaed grasshoppers, or locusts

Hancock (1911, p. 342), records the behavior of a male Carolina locust *Dissosteira carolina*. It was seen to start from the ground, mount into the air three feet; here he balanced himself in midair for several seconds. At first his wings vibrated very rapidly, but toward the end of the flight they became slower, and then he dropped to the ground, where he joined two other males; all three had an active greeting, all taking part in the stridulating. This had the effect of attracting the male of the sprinkled locust, *Chloealtis conspersa*, and in a moment he also joined in the jollification. "There seems no doubt but that the Acridians have a cultivated ear for grasshopper music, aside from its mere secondary sexual attraction."

Fulton (1928) observed the sound-making, and incidentally the hearing, in a species of grasshopper, *Circotettix coconino*, in Arizona. This species "effects periodical community outbursts of a loud, rattling noise made with the wings while putting on an exhibition of stunt-flying." At intervals of about one-half hour, Fulton would hear some of these grasshoppers flying in the distance. The sound would approach, and suddenly several of the insects nearby would take to the air, and make the desert ring with a terrible clatter. Then they would settle down and he would hear the wave of disturbance passing on to other parts. He says in conclusion, "How do these grasshoppers, resting on the ground, often under the plants, know when it is time to perform their aerial antics, except by a sense of hearing?"

Richards (1927) remarks that in some grasshoppers, *Psophos stridulus* and *Stauroderus scalaris*, there is an additional mechanism by which the wings make a loud rattle when the male, who is more aerial than usual, is traveling through the air. There is ample evidence that the males stridulate to excite the females and also sometimes in rivalry with one another.

Poulton (1896, p. 233), says that the male of *Psophos stridulus* has a special call which he utters only in the presence of the female. His observations also show that in several species of grasshoppers only the male stridulates at all, or at least persistently, in the presence of the female and that sometimes two or more males will stridulate near the same female.

Weaver's studies (1935) are summarized in *Biological Abstracts* as follows:

> The threshold of auditory sensitivity of four grasshoppers was determined from the electrical response of the nerve leading from the tympanal organ. These insects proved very insensitive to low frequencies. Near the lower limit it required for threshold stimulation a sound of about 95 db. above human threshold. With rising pitch the auditory sensitivity increases until at 10,000 cycles it closely approaches that of man. Beyond that point the sensitivity decreases until the upper limit is reached around 20,000 cycles.

Faber (1929) is summarized in *Biological Abstracts:*

> The males of each species produce a certain number of other sounds in addition to their ordinary

audible expressions. For example, *Chorthippus parallelus* shows seven kinds of stridulations which express four different conditions: the ordinary song, the rival song, the courting song and the mating song. In courtship almost all species show a striking diminution of tone strength as compared with their other sounds. In *Stauroderus biguttatus* at the height of courtship there appears a special form of stridulation which produces a scarcely audible sound. Rivalry of males was noted for *S. mollis*, where there is a reciprocal answering of males. The exchange of rival songs occurs in all species after reciprocal hearing. In *S. bicolor* the exchange of the chirps of the males has also been shown to be of the nature of rival songs which can be induced through imitation. The importance of the rival song is that it increases the eagerness of courtship and causes a collection of males around a female.

Katydids

Hancock (1911, p. 102), observed a male "arboreal" katydid, *Cyrtophylum perspicillatus* one September, commencing to stridulate each evening between 6:15 and 6:30, and no artificial sounds or mimicking could induce him to start earlier. When this one in the tree began to sing, another male which was kept in captivity would start almost simultaneously with him, but when the latter was kept indoors, so outside sounds were excluded, he failed to show any sympathetic reaction. Hancock says that it certainly seemed that he was awakened to activity by recognizing his neighbor's sounds.

Discussing the "swordbearer" katydid, *Conocephalus attenuatus*, Hancock (p. 337) exclaims: "What a picture this cone-head katydid presents during the height of his musical performance. In answering his rivals his enthusiasm seems to rise to supreme heights, as signified by the energy exercised in rubbing his wings together in rapid vibration."

Allard (1929, p. 576), verifies Caudell's statement that the female conehead, *Neoconocephalus robustus*, when handled, stridulated like the males. He finds also that the females of other species of katydids in the field emit a characteristic call of their own. "These call notes appear to be of the nature of true sex calls or invitations to the males, for a number of these in every instance at once congregated about her," some of them flying from the shrubbery near by. Allard has observed this behavior in the females of the bush katydid, *Phaneroptera curvicauda*, the round-winged katydid, *Amblycorypha rotundifolia*, and the larger angular-winged katydid, *Microcentrum rhombifolium*.

He also says that he came upon one of the most remarkable instances of perfect synchronism in a group of cone-headed katydids, *Neoconocephalus exiliscanorus*, rasping out their "dzeet—dzeet—." From time to time one or another would pause after the usual series of 18 to 25 notes.

> When it again joined the chorus its notes were always perfectly timed to accompany those of the other singers. Here for a long period of time this dropping out and taking up the muscial play was indulged in, but always with the same perfect synchronism with its fellows.

Of the bush katydid, *Phaneroptera curvicauda*, he says,

> I had at one time a female in captivity in my bedroom which would lisp out responses to my own lisping mimicry as often as I dared stimulate it. In tests of this katydid I stepped away slowly the entire length of the room, lisping so low as barely to hear it myself, and yet it heard it and responded promptly." He is thoroughly convinced that insects of this group hear sounds, for he says, "That all insect instrumentalists hear their own sounds I have not the slightest doubt, for I have positive evidence that their hearing is exceedingly acute.

Fulton (1928) says that "the fact that certain species of Orthoptera synchronize their notes seems to me conclusive evidence that they can hear each other." With this in view, he experimented on *Amblycorypha rotundifolia brachyptera*. The synchronism exhibited by ten males was almost perfect. After observing the song

of the whole group for two nights, the experimentor removed four of them to another cage after first removing from each the front tibiae containing the tympanal organs. Thereafter the synchronization in this group was completely ruined, while it continued as before in the cage of controls.

Fulton then got still more remarkable results on the Nebraska conehead, *Neoconocephalus nebrascensis*. Separating four males into two lots, and kept out of hearing range of each other, it was found that the synchronism of each couple was perfect. The front tibiae of one pair was then removed. On the second evening after the operation these two coneheads were singing with a conspicuous lack of coordination; at the same time the normal coneheads in the other cage were keeping up perfect synchronism.

Crickets

In spite of the fact that Lutz (1924) takes the conservative view of the auditory powers in insects, he states (p. 356) that while breeding crickets for other purposes he had hundreds of them under constant observation, and "it seemed to me that I could tell by listening to the males whether they were courting females, defying other males, or just passing the time." Inasmuch as he is not the one for whose edification the performance was done, won't he please give the crickets credit for doing at least as well as he did?

Lubbock (1888, p. 63), mentions that Brunelli kept and fed several male crickets, *Gryllus viridissimus*, in a closet, and they continued singing all day, but a rap on the door would stop them instantly. By practice he learned to imitate their chirpping; when he did this at the door, at first a few would answer him in a low note, and then the whole party would take up the tune and sing with all their might.

That the tympanal organs in field crickets are auditory in function is supported by the ingenious and controlled experiments of Baier (1930). Crickets previously conditioned to life in cages were placed, with sexes segregated, in different rooms sufficiently distant to be beyond the range of sound perception. A microphone, placed in the cage of males, was connected by telephone with a receiver in a cage of females of the same species. The females approached the receiver with actively moving antennae and performed movements indicative of search for partners. When the current was interrupted, they moved away from the receiver, but as soon as the connection was re-established they came to the receiver again. The females whose tympanal organs had been excised failed to respond, as did also those which had been locally anaesthetized with ethyl-chloride. Phonograph records of the male stridulatory notes produced the same response as the living insects.

Regen (1912), by controlled experiments and the use of phonograph records, got some important results with field crickets, *Liogryllus campestris*. Females responded to the song of the male on the phonograph, and ceased to respond when the tympanal organs were removed. He proves conclusively that the sound, and not odor or sight, attracts and directs the female toward the male. He further tested the auditory ability of the females by placing on the floor two glass vessels, one lined with black paper and the other transparent. Into the opaque jar he placed a chirping male, and into the transparent jar a quiet one. Normal females ran to the vessel containing the invisible, chirping male, but ignored the other one with its male in clear view. Females whose tympanal organs on the forelegs had been deleted did not react

to either vessel. That the response was not due to an odor liberated by the movement of the male's wings when chirping was shown by removing the edges of the wings, so the motion, while otherwise unchanged, was noiseless; the response of the females ceased.

Regen (1926) carried on experiments to test the influence of artificial sounds on the stridulation of the cricket, *Thamnotrizon apterus*. He finds that a Galton whistle, a bell, etc., and the chirping of other species interfered with the chirping of this cricket, and that the "S" sounds of the human voice called forth their response. Tests were also made to determine the highest pitch to which they would respond.

Baumgartner (1911) says the female mole-cricket, *Gryllotalpa borealis*, has a loud, distinct chirp in the burrow. It usually consists of a single note, but it may be repeated at short intervals. The note is less shrill than the ordinary call of the male. Both sexes use their calls as a means of recognition in the dark burrows, and especially when digging new tunnels.

Weaver and Bray (1933) experimented on auditory nerve impulses in crickets and grasshoppers. This consisted in picking up electrical changes produced in the tissues as a result of sound stimuli, amplifying these changes and conducting them to a telephone receiver where they were observed as sound. Responses were observed in katydids ranging from 800 cycles per second to well above the limit of human hearing; in crickets, from 300 to 8000 cycles. The response was a slushing noise, and was the same in quality regardless of the frequency of the stimulus.

Tree Crickets

Shull is quoted by Allard (1930) as having observed two snowy tree crickets, about five feet apart, chirping in such accurate unison that he did not at once realize that there were two of them. Soon one stopped; the other hesitated, chirped weakly and even lost a beat. After an irregular solo of several minutes, the other cricket resumed. At the first chirp, the first singer struck a note out of tune, then lost a beat as if startled; it next voiced a half-dozen weak, uncertain chirps, then increased in intensity until the two crickets were again chirping in exact unison. Allard remarks that this behavior would imply that the crickets not only hear their own sounds, but also were attempting to preserve a unison in them.

Allard (1929, p. 583), says from his own observations that many insects not only chirp in small groups, but a number of them appear inclined to bring their notes into synchronism with those of their fellows. "This procedure seems somewhat remarkable, and some . . . have been inclined to question this behavior. Synchronous chirping is an undoubted fact, however, and there is no reason why an insect or bird should not in some instances perceive rhythm and keep step as well as a human being." He is convinced that the snowy tree-cricket and also the little tree-cricket, *Cyrtoxipha gundlachi*, prefer to chirp in unison with their fellows. By an imitation of their noises he has led chirping crickets to speed up their rate noticeably in order to keep pace with him.

Allard (1911) describes the stridulation of the shield-backed grasshopper, *Atlanticus pachydermus*, and says that several times while watching them by lantern light he lisped an imitation of the notes and got an immediate response.

Fulton (1925, 1928 a, 1928 b) has shown in important experiments that tree crickets, *Oecanthus niveus*, actually hear sounds,

and do so with the tympanal structures on the fore tibiae. In control experiments, they were found to chirp in unison "as if a single cricket were singing." In another lot with the forelegs amputated, the chirping was quite different, without any rhythmic unison whatever, producing "an utter confusion of notes."

Fulton (1933) gives the views of some other investigators as well as his own on the sound making habits of certain female Tettigoniidae. The female call is made in direct response to that of the male; this of course indicates that the female must have heard the sounds. He quotes Riley (1874) who describes the song of *Scudderia furcata*, and says "the call is occasionally responded to by a faint chirp of the females produced by stretching out their wings as if for flight." He says the prolonged, rattling song of *Microcentrum rhombifolium* is "invariably answered by a sharp chirp or tschick from one or more females who produce the sound by a sudden upward jerking of the wings."

Fulton himself observed *Scudderia texensis*. He heard a male singing in the yard one night, and immediately after it sang, a brief series of faint, tapping sounds came from a cedar tree. With a flash-light he located the female and saw it produce the sound by working the tegmina in a manner similar to the male. Her reply always came about a half-second after the conclusion of the male's song. On another night he heard, at a distance of about thirty feet, a faint sound like "chp" following the prolonged ticking song of *M. rhombifolium*; this was repeated almost every time a male sang within a radius of forty yards. He located the female and watched her make the noise by spreading and closing the dorsal edges of the tegmina. He actually found that the males come to the females for mating. "The females did not move from the places where they were first discovered. If the males are guided only by the faint replies made to their songs, they must have a remarkable ability to locate sounds."

Insects often make sounds, says Allard (1929) for the same reason that birds and humans sing, "because they love sound and find it a means for self-expression; it is a part of their lives." Song may in some instances have a sexual significance, but the theory ascribing sound to sex in insects has probably been much overdone.

I have heard the snowy tree-cricket chirp at the rate of about 90 times per minute all night long. Think what this means; 5400 chirps per hour, 64,800 chirps in a 12-hour night, nearly 4,000,000 chirps in a period of 60 days, demanding the muscular energy of 16,000,000 wing strokes on the basis of four strokes for each chirp. What is it all about? Sex alone does not explain it; no cricket needs to chirp itself to death—chirp a cool million or five million times day and night in one bush to win the momentary attentions and embraces of a silent, lonely female in the vicinity.

Cockroaches

Because roaches do not make sounds that human ears can hear, and because students have been unable to detect organs of hearing in their bodies, roaches have generally been regarded as dumb.

Miall and Denny (1886), in their authoritative book on the roach, conclude that "the auditory organs are best developed in such insects that produce sound as a call to each other. The cockroach [*Blatta orientalis*] is dumb, and it is therefore not a matter of surprise that no structure which can be considered auditory should have been detected in this insect." The attitude of these authors in the matter of sound perception has set the standard, and students generally accept this opinion. Clarence L. Turner (1916) reflects this attitude when he says "the sense of hearing is obviously not a factor in the sexual

activities in the roach, for there are no organs for the reception of sound." Charles H. Turner (1913), however, records on the contrary that while doing other experiments with this roach he noticed that "when the tinners were fixing some guttering of a near-by house, the roaches were quite responsive to certain noises made by the tin." A meager observation by Graber (1882) mentions that a *Blatta*, running about on the floor, would stop for an instant when the strings of a violin were struck, or in another case, a blinded specimen hung by a thread became violently agitated at a sudden tone from a violin.

Some interesting work has been done in a highly technical way by Pumphrey and Rawdon-Smith (1936 a). With the use of platinum electrodes brought in contact with an active nerve, the authors show that "a response from certain tactile receptors may readily be excited by auditory stimuli." Evidence is produced to show that the anal cercus of the cricket and the cockroach, *Periplaneta americana*, has a partly auditory function. On the other hand, so they say, it seems possible that the acoustic function of the cerci is merely incidental. While the difficulty of distinguishing between acoustic and vibratory stimuli for an organ such as the cercus is fully realized, the relative insensitivity of the organ to all but the lowest frequencies, together with the fact that in the cricket it is frequently in contact with the ground, leads us to suppose that its main function here is to mediate the detection of earth-borne vibrations. In the corkroach where the cercus is carried more or less erect, it seems likely that its function as a wind gauge may be equal in importance to its function as an acoustic organ. (See also same authors, 1936 b and 1936 c.)

EXPERIMENTAL EVIDENCE

The oriental cockroach, Blatta orientalis

The life histories of the three common species of cockroaches, *Blatta orientalis*, *Periplaneta americana* and *Paracoblatta pensylvanicus*, were studied during 1937 and 1938. (The identifications of the latter two species were kindly verified by Mr. Morgan Hebard of the Academy of Natural Sciences of Philadelphia.) These roaches were confined for the most part in large glass fish bowls. Close observation during that period has given me no indication that roaches can create sounds audible to the human ear. On the other hand, the evidence from several incidents has led me to believe that they may be able to hear certain sounds. While searching for tangible proof of this, I often sat gazing into the bowls containing many roaches. On one such occasion, during an approaching storm, the wind banged the door, and what I saw then induced me to plan experiments to test their auditory powers.

The roaches often rested on a pyramid of cardboard which occupied the center in each glass container. When the door banged, a panic occurred among half of those that were resting quietly on the pyramid before me; the remaining half-dozen did not move. This raised in my mind these questions: Did the roaches actually hear the sound, or did the vibration of the bang cause the table or the container to shake and induce them to react through the sense of touch? If one or the other, why did some scuttle to safety and others remain quiet? The table on which the bowl rested was near the door; did some of them see the movement of the door and react through the sense of sight? Both the vibrations of the table and the sight of the moving object

were factors which may have influenced their behavior, so I decided that in further experiments these two probable influences must be excluded.

To this end, a screen was placed between the container and the door, so the roaches could not possibly see its motion. Precautions were also taken to prevent any vibrations other than sound-waves from reaching them; this was done by placing large pads of cotton wadding under each table leg, under the fish-globe which rested on the table, and under the glass lid that covered the globe. The latter method left open spaces between the props of cotton through which sound could enter, and the cotton prevented the lid from noisily vibrating against the glass. Experiments were then carried on by purposely banging the door from time to time (Series A), until the banging of the door caused a large portion of the plaster ceiling to crash to the floor. After this cataclysm, methods of a more scientific nature were followed (Series B). The early experiments (Series A) were, however, very valuable, for they suggested the plan for the later work.

Experiments: Series A

Exp. 1. June 23, 1937. Door banged and four of the six roaches in the jar gave a sudden start; two of these ran to the floor. Two of them gave no response.

Exp. 2. August 25, 1937. 9:30 p.m., 86° F. Three females on pyramid; door was banged; one gave a quick jerk, two did not move.

Exp. 3. August 27, 1937. 8:00 a.m., 80° F. Three roaches, one female and two males, were on top of pyramid; banged the door five times at intervals of one-half minute. First bang brought no reaction; second bang brought a slight movement of the female only; third bang brought a marked jerk from the female; fourth bang saw the female run down the incline for an inch and stop suddenly, while the two males reacted for the first time, giving a quick jerk; one moved no further, and the other ran for a distance of an inch and stopped; at the fifth bang the female ran to the floor and hid under a cardboard, while the two males ran down the incline for a short distance and stopped.

Exp. 4. One half-hour later. Two males and one female same as in last experiment; these and one new male were resting on pyramid. First bang, the two old males and one old female dropped to the floor and ran under cover; the new male refused to move and was now the only one exposed to view during the subsequent four bangs; this male remained adamant and refused to budge during the entire process.

Exp. 5. August 27, 9 p.m., 82° F. Two females on cardboard pyramid. With the first bang, both ran a short distance and stopped.

Exp. 6. August 27, 9:40 p.m., 82° F. One female and one male on pyramid. Five door-bangs at one-fourth minute intervals. The female reacted to all five bangs, very strenuously to the first two, feebly to the next two, and merely a slight jerk at the last; the male reacted to only one, the third, and this with a jerk.

Exp. 7. August 27, 9:50 p.m. 82° F. Only one female exposed; five bangs given at intervals of one-fourth minute. With the first, she rushed down the incline for two inches and stopped; at the second she ran to the other side of the pyramid and stopped; to the last three she gave no further reaction.

Exp. 8. September 1, 8:30 p.m., 90° F. Nymph in the last instar. Five bangs at intervals of one-fourth minute. With the

first, it ran three inches and stopped; at second and third, it ran further; at the fourth and fifth, there was no response.

Exp. 9. Last test repeated five minutes later. With first bang the nymph gave a sudden jerk; it gave no reaction whatever to the other four.

Experiments: Series B

In the preliminary experiments we have evidence that roaches possess the ability to perceive sounds and that they react to them by a jerk or a short run. On the other hand, some individuals give no reaction whatever to loud sounds; this may signify one of two things: either certain ones are deaf to these sounds, or all hear them but certain individuals inhibit any outward response.

In the present series of experiments, I intend to test their reaction to some sharp sound similar to that of the door-banging, and, in addition to this, to test their reaction to sound-waves of various known vibrations. For producing a sharp sound, a galvanized wash-tub was banged with a small fireplace shovel. For the planning and setting up of an instrument for producing sound of a known number of vibrations per second, I am indebted to my son David, who installed a device for producing sounds varying from a frequency of 25 vibrations per second upwards to one of 6000 vibrations. He describes the instrument as follows:

> The sound impulses were generated by an audio-oscillator with a continuous frequency range of 25 to about 6000 vibrations per second. The circuit employed was the conventional one using a neon glow lamp in connection with fixed condensers and a more variable resistance. This circuit gives a saw-tooth wave form instead of the more usual sine wave form. These sound impulses were amplified by a four watt audio amplifier, and reproduced through a dynamic loud speaker. The loud speaker was suspended by springs from the ceiling in order to eliminate the possibility of vibrations reaching the roaches through the table, or through any other medium than through the air. While this source of audio power left much to be desired from the standpoint of the physicist working in sound, due to the non-sinusoidal character of the wave-form, and due to the fact that a slight amount of 60 cycle hum was introduced into the output from the power lines, it was considered perfectly adequate for the work in hand.

A platform at a lower level than the loud speaker, and two feet away, was set up on the table. A jeweler's tray, with a velvet floor which would give the roach a foothold, was placed on the platform, and finally the arena was made by placing a tin ring, five inches in diameter and four inches high, on the velvet-covered tray. A thick padding of cotton and felt was placed beneath the tray, beneath the platform and also under each leg of the table, to prevent vibrations other than aerial sound-waves from reaching the roaches. The stock of roaches, each numbered and placed in a separate small jar, was kept in a room at the extreme opposite end of the house where, behind closed doors, they could not hear (and therefore could not be influenced by) what was going on in the laboratory. They were carried into the laboratory one at a time and dropped into the arena where the tests were given. The earlier tests were made at intervals of ten seconds, but later at intervals of one-half minute.

The results with the audio-oscillator during the early part of the work were principally negative, and I decided to introduce the loud, sudden sound. By hanging the inverted wash-tub over the back of a chair and striking it with the shovel, I was able to create a bang equal to, if not louder than, the banging of the door. The tub-banging experiments were alternated with those of the audio-oscillator. Sheets were especially ruled and symbols were employed so that the results of each test could be quickly recorded.

The method was, therefore, to drop a roach in the arena where it would run around for a few seconds and then stop; immediately after it had quieted down a sound was given, and the roach either remained motionless or responded by running again or by giving a startled jerk.

Experiments on adult females

The work was carried on with 23 females, each kept in a separate container and each given several trials on many separate days. As tests were made, the results were recorded on specially ruled sheets, a sample of which is given in Table 1.

TABLE 1

*Sample of recording sheets used in testing hearing ability of individual cockroaches**

No. 16. Species: *B. orientalis*. Sex: Female adult

TRIALS	DATE 1937	TIME		AGE	STIMULUS	VIBRATIONS PER SECOND	TEMP.	TESTS										REMARKS
		A.M.	P.M.					1	2	3	4	5	6	7	8	9	10	
1	9/26		3:30	Young	T.B.		60	*	*	*	*	*						Tests given at intervals of 10 seconds
2	—		3:35		T.B.		60	*	*	*	*	*	*	*	*	*	*	
3	10/3	9:55				6000	70	—	—	*	—	*						
4	—	10:00			T.B.		70	—	—	*	*	—	×	—	—	—	—	
5	—	10:15			T.B.		70	*	*	×	*	*	*	*	*	*	*	
6	10/6		9:00			6000	70	*	*	—	—	—						All sound impulses given for period of 10 seconds
7	—		9:05			6000	70	—	—	—	×	—	—	—	×	—	—	
8	—		9:12		T.B.		70	—	—	—	×	×	×	—	—	—	*	
9	—		9:18			500	70	—	—	—	—	—						
10	10/9		1:40			6000	68	—	—	—	—	—						
11	—		1:43			6000	68	—	—	—	—	—	—	—	—	—	—	
12	—		1:47		T.B.		68	—	—	*	*	—	*	—	*	*	*	
13	—		1:53		T.B.		68	—	*	*	*	*						

* T.B., tub-bang; —, no reaction; ×, slight reaction; *, very definite reaction.

This table is self-explanatory. Each trial (first column) consisted of either five or ten tests (last series of columns). The abbreviation "T.B." under stimulus means tub-banging, and the number under "vibrations per second" is that used for experiments with the audio-oscillator. The symbols given in columns 1 to 10 under the heading "Tests" needs an explanatory remark: the asterisk indicates a complete and pronounced reaction; an X indicates a slight reaction; a minus sign indicates no reaction whatever. In order to simplify the results, I have omitted in the tables of summary (Tables 2, 4 and 6) the distinctions of slight and pronounced reactions, and have treated both reactions as one. In the combined trials 1 and 2, for example, we read that female No. 16 gave 15 responsive reactions to 15 bangs on the tub, at intervals of ten seconds. In Trial 4 we read that 7 negative results, 2 strongly positive reactions and 1 slight reaction were the behaviors of the roach. Again in Trial 6, when subjected to impulses of 6000 vibrations per second, and continued through Trial 7, the responses were poor. The results of the work on all 23 females are tabulated in Table 2.

This table shows that, at temperatures varying between 54° and 80° F., the 23 females were given 44 trials involving 370 tests with a loud, metallic bang. The results, tabulated in columns 6 and 7, show 122 negative and 248 positive re-

TABLE 2

Tabulation of results of hearing tests made on 23 adult female B. orientalis cockroaches

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
			TUB BANG				1000 VIBRATIONS				6000 VIBRATIONS				
♀ NO.	DATE 1937–1838	TEMP. F.	No. Trials	No. Tests	Negative	Positive	No. Trials	No. Tests	Negative	Positive	No. Trials	No. Tests	Negative	Positive	REMARKS
2	9/10	74	—	—	—	—	—	—	—	—	1	5	2	3	
3	9/10, 9/12	70–74	—	—	—	—	—	—	—	—	2	10	8	2	
5	9/26	54	1	10	8	2	—	—	—	—	—	—	—	—	
7	9/28, 9/29, 9/30	58–70	3	25	13	12	1	5	5	0	1	5	5	0	
12	10/5	80	2	20	8	12	—	—	—	—	4	30	30	0	
13	10/6	68	1	5	1	4	1	10	10	0	2	10	10	0	
16	9/26–10/9	60–70	7	60	18	42	—	—	—	—	5	35	29	6	
21	10/7	62	1	5	0	5	—	—	—	—	1	5	5	0	
23	10/9	66	2	15	14	1	—	—	—	—	2	10	10	0	Nearly dead; has only 5 legs
24	9/8	72	—	—	—	—	—	—	—	—	1	5	4	1	
32	9/26	62	3	25	15	10	—	—	—	—	—	—	—	—	Very old; died next day
34	9/22–10/3	64–80	6	60	8	52	1	5	5	0	2	10	10	0	
"	10/3	70	1	10	2	8	—	—	—	—	—	—	—	—	Antennae off
44	9/24	70–76	4	35	4	31	—	—	—	—	1	5	5	0	
66	4/30	68	1	10	3	7	—	—	—	—	2	20	20	0	
67	4/28–5/28	62–80	1	10	1	9	—	—	—	—	5	40	40	0	
68	4/36	64	1	10	4	6	—	—	—	—	2	20	20	0	
70	5/22	70	2	10	3	7	—	—	—	—	3	15	15	0	
74	5/3 –5/30	72–80	1	5	1	4	—	—	—	—	4	35	14	21	
100	5/29	72	2	10	8	2	—	—	—	—	1	5	5	0	
101	5/29	78	1	10	3	7	—	—	—	—	1	10	10	0	
105	6/1	80	1	10	4	6	—	—	—	—	1	10	4	6	
106	6/1	80	2	15	3	12	—	—	—	—	1	5	5	0	
109	6/1	74	1	10	1	9	—	—	—	—	1	10	9	1	
Total.....			44	370	122	248	3	20	20	0	43	300	260	40	
Per cent.....						67%								13.3%	

sults; in other words, 67 per cent of the tests indicate that adult females heard and responded to the loud, sudden noise. The audio-oscillator tests (columns 8 to 11) at 2000 vibrations per second gave no positive reactions whatever; at 6000 vibrations per second (columns 12 to 15), 40 out of 300 tests (or 13.3 per cent) gave positive results. This percentage is so small that one would be tempted to disregard these results entirely, except for the fact that the 40 good responses came from only 7 females. This indicates either that certain females have a more acute sense of hearing than others, or that, because of old age or other causes, they are less able to inhibit reaction to sound waves of 6000 vibrations. Female 74 gave a good account of herself, having responded to 6000 cycles in 21 out of 35 tests; female 16 responded equally well in both banging and vibration tests, while female 105 responded in 6 out of 10 tests at 6000 vibrations. One individual deserves special mention: female 34 went through the last ten tests with her antennae removed at their base; in this condition she reacted in 8 out of 10 tests. This indicates at least that the antennae are not the seat of hearing. One might suspect that negative results are due to fatigue from excessive testing, but a careful check shows this is not true. Insects, of both sexes and also nymphs, which gave negative results in the vibration tests often responded to the louder test immediately afterward, as may be seen, for example, in Table 1.

TABLE 3

Sample of record made by a nymph (¾ grown) in hearing-ability tests

No. 4. Nymph ¾ grown. Species: *B. orientalis*

TRIALS	DATE	TIME A.M.	TIME P.M.	AGE	STIMULUS	VIBRATIONS PER SECOND	TEMP.	TESTS 1	2	3	4	5	6	7	8	9	10	REMARKS
1	9/24		10:07	¾ grown	T.B.		70	*	*	*	*	*	*	*	*	*	*	
2	—		10:17		T.B.		70	*	*	*	*	*	*	*	*	—	—	
3	9/26		12:10		T.B.		60	*	*	*	*	*						
4	—		12:15			6000	60	—	—	—	—	—						
5	—		12:20		T.B.		60	*	*	*	—	*						
6	—		12:35		T.B.		61	*	*	*	—	—						
7	10/3		2:00		T.B.		70	*	—	*	*	*	—	—	*	*	×	
8	—		2:08		T.B.		70	—	×	—	×	*	×	×	×	×	*	Antennae cut off.
9	—		2:10		T.B.		70	*	×	*	—	—	*	*	*	*	—	Continuation of trial 8
10	10/6		8:00			6000	70	—	—	—	—	—						
11	—		8:05			6000	70	—	—	—	—	—						

Experiments on nymphs

The same method of experiment and the same tabulations were made for the nymphs as for the adult females. These immature roaches were ½ to ¾ grown.

In Table 3 I present a sample record for one nymph (No. 4). This is to be read in the same way as the previous one on the adult female. It shows that this roach gave a good many positive responses to the sound produced by banging the tub. In Trials 1, 2, 3, 5, 6, out of 35 tests only 5 were negative; and for the ones tested with 6000 vibrations per second (Trials 4, 10 and 11) all were negative. In Trials 8 and 9, I find that the loss of antennae is

TABLE 4

Sound recordings of hearing tests on 17 nymphs

Nymphs ⅜ to ½ grown

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
			TUB BANG				500 VIBRATIONS				2000 VIBRATIONS				6000 VIBRATIONS				
NYMPH NO.	DATE 1937–1938	TEMPERATURE F.	No. Trials	No. Tests	Negative	Positive	No. Trials	No. Tests	Negative	Positive	No. Trials	No. Tests	Negative	Positive	No. Trials	No. Tests	Negative	Positive	REMARKS
4	9/24–10/6	60–70	6	45	8	37	—	—	—	—	—	—	—	—					
"	10/3	70	2	20	5	15	—	—	—	—	—	—	—	—	3	10	10	0	Antennae off
6	9/28–10/3	62–70	6	60	22	38	1	5	5	0	—	—	—	—	3	15	15	0	
9	9/29, 10/9	60–68	3	30	7	23	—	—	—	—	1	5	5	0	3	15	15	0	Had only 1½ antennae
11	10/ 4, 10/6	66–70	2	10	0	10	1	5	5	0	—	—	—	—	3	20	20	0	
13	9/23	78	1	10	0	10	—	—	—	—	—	—	—	—	2	10	10	0	
14	10/6	70	—	—	—	—	—	—	—	—	—	—	—	—	2	10	10	0	
20	10/ 6, 10/9	66–68	2	15	7	8	1	10	10	0	1	5	5	0	3	25	25	0	
22	10/9	62–64	1	10	2	8	2	10	10	0	—	—	—	—	4	20	20	0	
25	10/19	60	3	25	4	21	1	5	5	0	—	—	—	—	3	20	20	0	
43	10/3	66	2	20	4	16	—	—	—	—	—	—	—	—	2	10	10	0	
44	10/7	60–62	2	10	1	9	1	5	5	0	—	—	—	—	6	30	30	0	
45	4/21– 5/23	62–82	3	25	11	14	—	—	—	—	—	—	—	—	5	35	35	0	
79	5/3 – 5/26	72–78	4	40	23	17	—	—	—	—	—	—	—	—	4	25	25	0	
81	5/31	72	2	20	4	16	—	—	—	—	—	—	—	—	1	5	5	0	
84	5/30	82	3	25	11	14	—	—	—	—	—	—	—	—	2	20	20	0	
95	5/26	72	3	25	11	14	—	—	—	—	—	—	—	—	2	20	20	0	
98	5/3	82	1	10	7	3	—	—	—	—	—	—	—	—	1	10	10	0	
Total			46	400	127	273	7	40	40	0	2	10	10	0	49	300	300	0	
Per cent						68.2%													

no hindrance to perception of the loud sound.

Seventeen nymphs were tabulated in this way, and the results of the work are presented in Table 4.

Here again we see that the responses to

the audio-oscillator at various frequencies was nil, but the 400 tests using the loud bang as a stimulus, 68 per cent gave positive responses. Here too, as in the experiments on adult females, we find that the removal of the antennae is no hindrance to the perception of this sound.

I have thus far been unable to distinguish the sexes in nymph roaches, and it might be possible that in the immature stages one sex is more keen than the other in sound perception.

TABLE 5

Sample of record made by an adult male cockroach (No. 24) in hearing tests

No. 24. Species *B. orientalis*. Sex: Male adult

TRIALS	DATE	TIME A.M.	TIME P.M.	AGE	STIMULUS	VIBRATIONS PER SECOND	TEMP.	TESTS 1	2	3	4	5	6	7	8	9	10	REMARKS
1	10/1		10:30	Very old	T.B.		72	—	×	—	—	—					—	
2	—		10:35		T.B.		72	×	*	*	*	*	*	*	—	—	—	
3	—		10:40		T.B.		72	*	×	—	—	*	*	—	*	*	*	Continuation of
4	—		10:45			6000	72	*	*	*	*	*	—	—	*	—	—	Trial 2
5	—		10:52			6000	72	×	—	—	*	*						
6	10/3		10:30			6000	68	—	—	—	—	—						
7	—		10:45		T.B.		68	*	—	—	×	×	—	*	*	*	*	
8	—		10:45			6000	68	—	—	—	—	—						
9	10/5	8:30				6000	70	*	—	—	—	—						Asleep before test 1
10	—	8:35				6000	70	—	—	—	—	*	—	—	—	—	—	
11	—	8:42			T.B.		70	—	—	×	—	—	*	—	—	—	—	
12	—	8:47				6000	70	—	—	—	—	—						
13	—	9:00				6000	70	×	*	*	—	×	*	*	—	—	×	
14	—	9:07				1000	70	—	—	—	×	×						
15	—	9:15				1000	70	*	*	—	—	—						
16	10/5		8:00			6000	78	—	—	—	—	—						
17	10/5		8:05			6000	78	*	—	—	—	—						
18																		Died Oct. 7/38

Experiments on adult males

The conditions and methods of the experiments were the same for the males as for the nymphs and females. The work was carried on with 21 males.

Table 5 gives a sample record of one male, No. 24. There is one reaction which is especially noteworthy, in that it brings into work of this kind a new method of approach. I refer to Trial 9; here the male was permitted quietly to spend two days, without tests, in the arena on the experimental platform after having given negative results in the 6000-vibration test in Trial 8. On the morning of October 5 I watched this roach for half an hour and found that, to the best of my knowledge, it was asleep. I then suddenly gave the 6000-vibration sound and, to my great surprise, the roach gave a sudden leap. Had the insect been awake, it would undoubtedly have inhibited the response, as it did in the tests of Trial 8 and also in tests 2, 3, 4 and 5 of Trial 9. The success of this venture caused me to repeat the "sleep" experiment with male No. 58 (see Table 6), with the same result. Taken unaware, at the sound of 6000 vibrations he also gave a sudden leap, a reaction which he never repeated in the twenty-four tests which followed. A

TABLE 6

Tabulation of results of hearing tests on 21 adult male cockroaches, B. orientalis

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
			TUB BANG				1000 VIBRATIONS				6000 VIBRATIONS				
♂ NO.	DATE 1937–1938	TEMPERATURE F.	No. Trials	No. Tests	Negative	Positive	No. Trials	No. Tests	Negative	Positive	No. Trials	No. Tests	Negative	Positive	REMARKS
24	10/1– 10/5	68–78	5	45	21	24	2	10	6	4	10	65	46	19	Very old, died 2 days later
44	9/26	62	1	10	5	5									
50	4/20– 4/26	58–84	8	55	26	29	1	5	5	0	7	60	60	0	
51	4/21– 5/30	64–84	3	25	8	17	—	—	—	—	4	40	40	0	
52	4/ 4– 5/30	74–80	3	20	6	14	—	—	—	—	3	30	28	2	
54	4/21– 5/30	66–80	4	25	10	15	—	—	—	—	8	75	69	6	
57	4/25– 5/29	64–80	3	20	10	10	—	—	—	—	3	15	15	0	
58	5/27	74	4	25	13	12	—	—	—	—	4	25	24	1	Responded to 6000 when asleep
61	4/27	72	1	10	4	6	—	—	—	—	2	15	15	0	
62	4/27– 5/23	64–78	2	20	6	14	—	—	—	—	3	30	30	0	
63	4/27	78	1	5	2	3	—	—	—	—	2	20	20	0	
64	4/27– 5/23	72–64	3	25	19	6	—	—	—	—	4	35	35	0	
71	4/29– 5/22	70–72	2	15	11	4	—	—	—	—	2	20	19	1	
73	5/3– 5/30	80–84	2	10	7	3	—	—	—	—	3	15	15	0	
74	4/27	76	2	15	13	2	—	—	—	—	2	15	15	0	
75	5/1– 5/22	62–72	2	15	12	3	—	—	—	—	2	10	10	0	
76	5/1– 5/30	72–81	2	20	15	5	—	—	—	—	3	25	25	0	
77	5/1– 5/30	72–80	2	20	8	12	—	—	—	—	3	25	22	3	
99	5/29	78	1	10	1	9	—	—	—	—	1	10	10	0	
103	6/1	80	1	10	1	9	—	—	—	—	1	5	5	0	
107	6/1	78	1	5	0	5	—	—	—	—	1	5	5	0	
Total.....			53	405	198	207	3	15	11	4	68	540	508	32	
Per cent.....						51.2%				26.7%				5.9%	

new point of technique in experimental projects in hearing is brought out in this case; it is, as I said before, to catch them unaware during their sleep, and get reactions before they have time to consider how they should behave. The results of the work on all 21 males are presented in Table 6.

In this table we find the work on twenty-one males was carried on between September 26 and June 1, at temperatures that varied from 58 to 84° F. They responded to the loud bang in 207 out of 405 tests, or 51 per cent. In fifteen tests of 1000 vibrations given to two males, only one responded, and it did so in four out of ten tests. In the last four columns we have the details of male roach reaction to 6000 vibrations per second; in 540 tests we got only 32, or 5.9 per cent, positive responses. This result is so low that one is at first tempted to discard it entirely and conclude that male roaches do not hear vibrations of this intensity. When one examines the reactions of individual roaches, however, one must conclude that the males hear these vibrations but are masters at inhibiting any outward show of their having received these sound-waves. This conclusion is reinforced by what I have recorded for their behavior when 6000 vibrations were given to them when asleep and will also be further strengthened (for other sounds) in what I have to say under the heading of Series C. Referring again to individual reactions with this number of vibrations (last column) it is well to note that we got from one male three positive reactions out of twenty-five tests, in another, six out of seventy-five, in yet another, two out of thrity, and finally in two instances, one each out of twenty and twenty-five tests. The crowning glory, however, is male 24, who reacted to both 1000 and 6000 vibrations; in the former tests he gave four positive reactions out of 10, and in the latter, 19 out of 65.

This demonstrates quite clearly that at least one male reacted sufficiently well to prove that 6000 vibrations are heard. But why should one male give such good results in contrast to the negative or very poor positive results of the others? The reason is not difficult to find. The length of life of adults in this species is short, but that of the male is considerably shorter than that of the female. By the middle of September the males have practically all died off, and only rarely is one to be found. One such male had outlived his "three-score and ten", and was used in the experiments from October 1 to 5, and was known as No. 24. This male was therefore very, very old, and died two days after the conclusion of the experiments. He was, in fact, the solve survivor of his sex for the season. It seems incredible at first that one so old should still possess such an acute power of hearing. But the indications are that this male No. 24 responded so readily to sound waves because of and not in spite of its old age. Additional work on this problem will perhaps show that young males are much more successful in inhibiting reaction to sound than old ones are. Males in the state of old age and senescence, it seems, are unable to inhibit their reactions so successfully as do the younger males.

Additional observations on Blatta orientalis

An accidental observation led Dr. C. H. Turner (1913) to suspect that the oriental roach may be able to perceive sound, for he says, "One day when some tinners were fixing the guttering of a near-by house, the roaches were quite responsive to certain noises made by the tin." On the night of May 31, 1938, some excavating was being done about a half-mile from my home. I was watching a large glass cage

TABLE 6

Tabulation of results of hearing tests on 21 adult male cockroaches, B. orientalis

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
			TUB BANG				1000 VIBRATIONS				6000 VIBRATIONS				
♂ NO.	DATE 1937–1938	TEMPERATURE F.	No. Trials	No. Tests	Negative	Positive	No. Trials	No. Tests	Negative	Positive	No. Trials	No. Tests	Negative	Positive	REMARKS
24	10/1– 10/5	68–78	5	45	21	24	2	10	6	4	10	65	46	19	Very old, died 2 days later
44	9/26	62	1	10	5	5									
50	4/20– 4/26	58–84	8	55	26	29	1	5	5	0	7	60	60	0	
51	4/21– 5/30	64–84	3	25	8	17	—	—	—	—	4	40	40	0	
52	4/ 4– 5/30	74–80	3	20	6	14	—	—	—	—	3	30	28	2	
54	4/21– 5/30	66–80	4	25	10	15	—	—	—	—	8	75	69	6	
57	4/25– 5/29	64–80	3	20	10	10	—	—	—	—	3	15	15	0	
58	5/27	74	4	25	13	12	—	—	—	—	4	25	24	1	Responded to 6000 when asleep
61	4/27	72	1	10	4	6	—	—	—	—	2	15	15	0	
62	4/27– 5/23	64–78	2	20	6	14	—	—	—	—	3	30	30	0	
63	4/27	78	1	5	2	3	—	—	—	—	2	20	20	0	
64	4/27– 5/23	72–64	3	25	19	6	—	—	—	—	4	35	35	0	
71	4/29– 5/22	70–72	2	15	11	4	—	—	—	—	2	20	19	1	
73	5/3– 5/30	80–84	2	10	7	3	—	—	—	—	3	15	15	0	
74	4/27	76	2	15	13	2	—	—	—	—	2	15	15	0	
75	5/1– 5/22	62–72	2	15	12	3	—	—	—	—	2	10	10	0	
76	5/1– 5/30	72–82	2	20	15	5	—	—	—	—	3	25	25	0	
77	5/1– 5/30	72–80	2	20	8	12	—	—	—	—	3	25	22	3	
99	5/29	78	1	10	1	9	—	—	—	—	1	10	10	0	
103	6/1	80	1	10	1	9	—	—	—	—	1	5	5	0	
107	6/1	78	1	5	0	5	—	—	—	—	1	5	5	0	
Total			53	405	198	207	3	15	11	4	68	540	508	32	
Per cent						51.2%				26.7%				5.9%	

new point of technique in experimental projects in hearing is brought out in this case; it is, as I said before, to catch them unaware during their sleep, and get reactions before they have time to consider how they should behave. The results of the work on all 21 males are presented in Table 6.

In this table we find the work on twenty-one males was carried on between September 26 and June 1, at temperatures that varied from 58 to 84° F. They responded to the loud bang in 207 out of 405 tests, or 51 per cent. In fifteen tests of 1000 vibrations given to two males, only one responded, and it did so in four out of ten tests. In the last four columns we have the details of male roach reaction to 6000 vibrations per second; in 540 tests we got only 32, or 5.9 per cent, positive responses. This result is so low that one is at first tempted to discard it entirely and conclude that male roaches do not hear vibrations of this intensity. When one examines the reactions of individual roaches, however, one must conclude that the males hear these vibrations but are masters at inhibiting any outward show of their having received these sound-waves. This conclusion is reinforced by what I have recorded for their behavior when 6000 vibrations were given to them when asleep and will also be further strengthened (for other sounds) in what I have to say under the heading of Series C. Referring again to individual reactions with this number of vibrations (last column) it is well to note that we got from one male three positive reactions out of twenty-five tests, in another, six out of seventy-five, in yet another, two out of thrity, and finally in two instances, one each out of twenty and twenty-five tests. The crowning glory, however, is male 24, who reacted to both 1000 and 6000 vibrations; in the former tests he gave four positive reactions out of 10, and in the latter, 19 out of 65.

This demonstrates quite clearly that at least one male reacted sufficiently well to prove that 6000 vibrations are heard. But why should one male give such good results in contrast to the negative or very poor positive results of the others? The reason is not difficult to find. The length of life of adults in this species is short, but that of the male is considerably shorter than that of the female. By the middle of September the males have practically all died off, and only rarely is one to be found. One such male had outlived his "three-score and ten", and was used in the experiments from October 1 to 5, and was known as No. 24. This male was therefore very, very old, and died two days after the conclusion of the experiments. He was, in fact, the solve survivor of his sex for the season. It seems incredible at first that one so old should still possess such an acute power of hearing. But the indications are that this male No. 24 responded so readily to sound waves because of and not in spite of its old age. Additional work on this problem will perhaps show that young males are much more successful in inhibiting reaction to sound than old ones are. Males in the state of old age and senescence, it seems, are unable to inhibit their reactions so successfully as do the younger males.

Additional observations on Blatta orientalis

An accidental observation led Dr. C. H. Turner (1913) to suspect that the oriental roach may be able to perceive sound, for he says, "One day when some tinners were fixing the guttering of a near-by house, the roaches were quite responsive to certain noises made by the tin." On the night of May 31, 1938, some excavating was being done about a half-mile from my home. I was watching a large glass cage

of roaches when a blast of dynamite was discharged; this noise caused a panic among almost all of the eighteen roaches, practically all of them scampering for cover. A similar reaction was witnessed a few weeks later when a peal of thunder sent most of the inmates of the cage quickly to shelter.

Experiments: Series C

Blatta orientalis, Periplaneta americana, and Paracoblatta pensylvanica

Banging of doors, beating of tubs, peals of thunder, notes from a violin and hammering of tin gutters all bring forth a definite response from roaches, showing beyond the shadow of a doubt that they perceive soundwaves through the air. Since they apparently give forth no sound for the purpose of attracting mates, it is quite evident that this sound perception is for the purpose of hearing approaching enemies and fleeing from them. That being the case, why do we not get one hundred per cent positive reaction in all of the experiments? The only logical answer to this question is that roaches do hear sounds but inhibit outward responses. We know this to be so, because in those instances when we came upon them unawares during time of sleep, we got favorable reactions even under the most difficult tests, i.e., with sounds of 6000 vibrations.

Nature has apparently endowed the roach with the ability to hear dangerous sounds, so that it can escape to safety. She has also endowed them with mental machinery which causes them to remain stark still and inhibit any movement in the face of danger. This is seemingly a paradox. Evidently there is an Ethiopian in the woodpile somewhere, and I think I have ferreted him out. All of the experimental work with roaches was done in broad daylight, or, when it was done at night, it was carried on with the aid of a 50-watt electric bulb glowing directly over the expermental platform. Daylight or artificial light was necessary in order to observe the slightest movement of each roach. But one must not forget that roaches are insects of nocturnal habits and in all of the work they were subjected to experiments at hours that were unusual and unnatural to their normal period of activity. Perhaps the inhibition of response was due to this unusual condition. Some such protective adjustment is what would be expected from a nocturnal insect during the daylight hours when they normally should be within their dark crevices. It would be suicide for them to rush from their places of safety during daylight hours at the sound of danger, but in the darkness of night, when they fare forth on food-hunting expeditions, a sharp sound should cause them to retreat quickly to the crevices they had left. If sound experiments could be carried on in darkness, would the roaches likewise inhibit movement? Darkness is not conducive to good observation; but a method was worked out whereby the roaches could be tested in almost complete darkness.

Blatta orientalis

To this end, I set up the following device. Into a large, heavy plateglass aquarium (32 x 16 x 12 inches), I placed at one end several clay flower-pots, to provide hiding places for the roaches; at the opposite end I placed a low platform containing food. During the daytime the roaches hid themselves among the pots, but during the dark and quiet night they made their way to the opposite end for food.

After permitting them to become accustomed to their surroundings for about two weeks, I tested them on three suc-

cessive nights to see if the flashlight, dimmed by a covering of two layers of thin cloth, would cause them to run to their hiding places. I had previously learned that by switching the electric light on at night, I could get them to abandon food and courtship and run for cover. Now I wished to discover if rays from a dim flashlight, shedding just enough light for me to see what was going on, would be sufficiently low not to alarm them. I found, to my complete satisfaction, that they were not influenced by this very dim light, and that I could creep up to the cage and let the dim rays fall upon its floor without disturbing the many insects there occupied with courtship, eating or resting.

After becoming satisfied that there was no reaction to dim light, I began my "thumb-nail" experiments. This was carried on by snapping the thumb-nail against the wall of the glass container, thereby creating a sharp sound. This caused a very definite reaction from all the roaches. Whatever their position or condition at the time, they turned about and made for the direction of their hiding places. After a few seconds I repeated the snap with the nail against the glass, and this caused another forward movement with most of the population rushing for cover; by the time I had completed the third snap, all of the roaches had completely disappeared. It is interesting to note that the sound of my finger nail against the glass did not cause the roaches to move about in panicky manner, but they appeared to remember their hiding places, headed stright for them, and finally with the last snap (all three of which had consumed less than a minute) all had reached their crevices.

On June 2 and the six following evenings, these tests were repeated at about 9:30 p.m., and on three of the evenings an additional experiment was done at 1 a.m. There were always from fifteen to twenty adults on the floor, and in all nine of the trials of the three thumb-nail tests each given at short intervals, the entire population was driven completely to cover at the opposite end of the cage.

Their reactions in darkness differed from those of daylight in that all were in perfect accord in their movements toward their shelter when the sounds were made against the glass. Here were experiments on insects at a normal time of activity in their natural habitat. They had been in this box for several weeks, and they remembered the geographical position of each crevice; the work was carried on under conditions of darkness that were in accord with their normal activities. They heard sharp sounds in the dark when they were away from their crevices and acted voluntarily—or, one may say, instinctively—and beat a hasty retreat to a haven they knew. During the daylight hours, even though possessed with the instinct to run, indecision caused some to respond by movement and others by remaining quiet. This quick response is probably due not to darkness alone, but in part to the fact that the roaches were experimented upon in their own home, where every crevice and corner was familiar to them, and in times of danger they remembered their places of shelter and headed directly to them.

Here again the ghost of "tactile perception" bobs up; at first sight it may seem that the snapping of the thumb-nail against the glass may have vibrated the container, ever so slightly, and the reaction noted in the roaches may be due to tactile perception rather than auditory. There are two things that militate against tactile perception in these tests. It is unlikely that the snapping of the finger-nail against the glass would have caused

the heavy container (it was made of iron, slate and plate-glass, had a plate-glass cover and weighed at least fifty pounds) to shake. Also, often before a test was begun, I shook the table slightly and found it aroused no response in the roaches. Since these shakings did not elicit tactile reaction, one may safely say that the response to the thumb snaps must have been due to auditory perception.

There is still another test indicating auditory rather than tactile perception. I had about fifty adult oriental roaches of both sexes in a large tin candy-can. By dim light at night I would often tap the can with a pencil at intervals. This noise created a scramble by the roaches for cover under pieces of paper. Now in this case vibrations in the tin might have carried tactile as well as auditory stimuli; but that was not all. I soon discovered that tapping the tin can with a pencil caused active responses in two colonies of roaches in glass fish-bowls on another table near by. This latter incident seems to be an unquestionable case of auditory perception, since the roaches in the glass bowls were quite beyond the reach of any vibrations other than sound.

Further evidence that Oriental roaches respond to sound was obtained when the glass lid of one of the jars was lifted and accidently slipped from the fingers. The noise, as the lid hit the jar, caused the roaches within to run for cover. They, however, may have been influenced by the movement of the air within the jar or by the vibration of the vessel, rather than by the sound of the falling lid; the significant point is that roaches in neighboring jars, some little distance away, also reacted in the same way. To make sure that nothing but sound influenced these reactions, the experiments were repeated several times after the jars had been well upholstered with wads of cotton. The results were always the same; some of the inmates of the neighboring jars always moved with alarm. Finally, to eliminate all possibility of tactile influences, the neighboring jars were removed to a nearby table and the test repeated. The results were the same as before. These experiments were carried on during daylight hours but in no case did all the roaches so react. Later, when the same tests were made at night with the aid of a dim flash-light, the reactions of roaches in neighboring jars were positive to the extent of 100 per cent of their number. The experiments described for adult Oriental roaches were also tried on adults and large nymphs of the American roach with the same positive results.

There is yet another by-product of these thumb-tapping experiments. The work was carried on for six successive nights, but toward the end it took louder taps, and more of them, to frighten the population to run for shelter. The roaches were learning that these sounds were not of life significance, and refused to respond as rapidly as they did early in the work. In the first few days, three taps and one minute of time was all that was necessary to bring the population to their places of shelter. The work was carried incidentally for several nights beyond the sixth; on the tenth and eleventh nights it required twelve to fourteen taps, consuming several minutes, to get them all into their crevices.

Periplaneta americana

The same thumb-tapping experiments were practiced a month later on American roach nymphs in the last instar. The results were almost identical with those for the same tests on the oriental roaches. Three snaps of the thumb at measured intervals of about a half-minute brought the flock to the crevices at the opposite

end of the box. It was with greater difficulty, however, that the tests were begun, because these roaches were more sensitive to the dim rays from the flashlight than were the oriental roaches. It required about six nights of practicing with a dim flashlight before they became conditioned to it and did not run. After they had become indifferent to this, I inaugurated the tests, and was successful in getting them to respond to the sounds in the dim light. There were twenty large numphs in these experiments.

Tests were made on three nymphs $\frac{1}{4}$, $\frac{1}{3}$ and $\frac{7}{8}$ grown, of the American roach.

In Table 7 we see that all three nymphs responded to the banging of the tub, giving 61 positive responses out of 90 tests (67.7 per cent), and that none of them responded to 6000 vibrations per second.

Paracoblatta pensylvanica

A few wood-roaches were trapped in the barn and subjected to tests of tub-banging and also to vibrations of 6000 cycles.

Here (Table 8) we see adults of both sexes responding equally well to the two kinds of tests. In the tub-banging tests, 33 out of 55 (or 60 per cent) responded positively, and in the 6000-cycle experiments, 40 in 76 tests (52.6 per cent).

The behavior of this species on the ex-

TABLE 7

Results of hearing tests made on three nymphs of Periplaneta americana

1	2	3	4	5	6	7	8	9	10	11	
NO.	DATE 1937	TEMPERATURE F.	TUB BANG				6000 VIBRATIONS				AGE
			No. Trials	No. Tests	Negative	Positive	No. Trials	No. Tests	Negative	Positive	
10	9/26	64	2	20	6	14	2	10	10	0	$\frac{1}{4}$ grown
26	10/19	59	1	5	0	5	—	—	—	—	$\frac{1}{3}$ grown
55	4/21	67–80	7	65	23	42	5	45	45	0	In last instar
Total			10	90	29	61	7	55	55	0	
Per cent						67.7%					

TABLE 8

Results of hearing tests made on adult wood roaches, Paracoblatta pensylvanica

1	2	3	4	5	6	7	8	9	10	11	12	
SEX	NO.	DATE 1938	TEMP. F.	TUB BANG				6000 VIBRATIONS				REMARKS
				No. Trials	No. Tests	Negative	Positive	No. Trials	No. Tests	Negative	Positive	
F	108	5/30	72	2	10	6	4	2	16	6	10	Ate bread between tests
F	111	5/31	76	2	10	6	4	1	5	3	2	Became adult 5/17
F	112	5/31	80	1	10	2	8	3	30	11	19	Became adult 5/17
M	113	5/31	74	1	10	2	8	—	—	—	—	Became adult 5/15
F	114	6/15	76	2	15	6	9	3	25	16	9	
Total				8	55	22	33	9	76	36	40	
Per cent							60%				52.6%	

perimental platform differed decidedly from that of the oriental roach. The latter would give a quick jerk or run, but *Paracoblatta* would always jerkily move toward the left. In this manner, with hardly any movement of the rear part of the body, with each alarm they would swing the fore-part of the body a little more to the left to the extent of about thirty degrees for each move; they would thus describe about one-third of a circle in four reactions.

The behavior of Female 114 was of interest, for she always reacted a few seconds after the sound had ceased.

SUMMARY AND DISCUSSION

The observational and experimental data herewith presented definitely establishes the fact that the oriental roach, *Blatta orientalis*, perceives and responds to such sounds as banging of doors, peals of thunder, blasts of dynamite and the beating of metal tubs. Both sexes in the adult stage respond to all these sounds, while nymphs of unknown sex respond to some of them. The percentage of responses to the tub-banging experiments, for example, was 68.2 per cent for the nymphs, 67 per cent for the adult females, and 51.2 per cent for the adult males.

Tests with the audio-oscillator brought forth very few responses; this does not imply, however, that they did not hear these sounds, but rather as the comments in earlier pages indicate, the sound was heard but response was withheld. This inhibition of movement was very probably due to the fact that the insects, naturally nocturnal in habit, were subjected to experiments during daylight hours or during the night with artificial lighting, and also while they were away from their natural haunts. With roaches under normal conditions in their own homes, in other tests by snapping the thumbnail against the glass, we got 100 per cent response from adults of both sexes for the Oriental and also the American roach.

In the wood-roach, *Paracoblatta pensylvanica*, we find the insects responding to the banging experiments as well as the 6000 vibrations; in the former they reacted in 60 per cent of the tests, and in the latter, 52.6 per cent. The smaller nymphs of the American roach gave favorable responses to the tub-banging tests in 67.7 per cent, but none at all to 6000 vibrations.

CONCLUSIONS

A survey of the literature on the subject of sound perception leaves one with the conviction that the great weight of evidence is in favor of sound perception or hearing in insects, and all this without bringing to the aid of the problem the proofs advanced on morphological grounds. Time, after all, seems to be the perfect judge, and the early experiments and results that have long been viewed with suspicion, now presented in the light of recent investigations, are regarded in a different light. Where observers have obtained negative results, it may in some cases have been due to technique, as compare for instance the observations by Hopkins (Marlatt 1898) on cicadas with those of Fabre. In other cases it is a question whether the sounds used were of a kind that meant anything biologically in the lives of the insects; in other cases, surroundings may have caused a difference, as when ants were observed at home in their own nests or in places strange to them.

Insects were in song long before man came upon earth, and "there is good palaeontological evidence that grasshoppers not greatly different from present day forms fiddled away among the carboniferous ferns and enlivened the dense atmosphere of preadamic times" (Riley,

1874); and Zeuner (1934) in tracing the evolution of fiddle and of ear in locusts and crickets from the upper Palaeozoic says in Tettigoniidae and Gryllidae, the ear in the tibia of the foreleg, is evidently older than the muscial apparatus.

Insects use sound primarily with biological meaning to call and charm mates, as in the crickets and katydids; to escape danger, as in the roach; to compete with rivals for mates; to call members of the same colony as in social insects; and finally to express the pure joy of living. To give biological meaning to the production of sound, it is necessary for the insects to be able to hear sound, and I think the evidence herein submitted points to that conclusion.

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CHROMAFFIN TISSUE AND PARAGANGLIA

By W. HENRY HOLLINSHEAD

Department of Anatomy, Duke University School of Medicine

INTRODUCTION

ALTHOUGH there is a voluminous literature on the subject of chromaffin tissue, and more especially on the adrenal medulla or its homolog in lower forms, a general consideration of the tissues frequently referred to as "paraganglia" does not seem to be available. Much of the early work on various aspects of this subject has been reviewed by Kohn ('02). In quite recent years, however, interest has been revived by the discovery of additional cell groups resembling chromaffin tissue in certain respects, and by new anatomical and physiological findings on some of the bodies previously described as chromaffin. The term paraganglion, originally synonomous with chromaffin tissue, has been extended by many writers to include those cell groups of non-chromaffin nature which they believe to be homologous with the true chromaffin tissue. It is proposed, then, to consider especially in this article the extra-adrenal mammalian tissues which have at one time or another been classified as chromaffin (chromophil, phaeochrome) or as paraganglia.

Among the tissues which have been thus classified are the abdominal chromaffin bodies, the coccygeal body, the carotid body, certain paraganglia in the region of the heart and great vessels, and the abdominal vagal paraganglia reported by Goormatigh ('36) in the mouse. In order to avoid too much confusion, it is proposed to discuss these structures in the order in which they have been listed above.

THE ADRENAL MEDULLA AND THE ABDOMINAL CHROMAFFIN SYSTEM

The now well-known reaction which the adrenal medulla gives with chromium salts, resulting in a rather characteristic yellow to brown coloration, apparently was first reported by Henle (1865). In 1890 Stilling observed, during the course of some experiments on the adrenal gland, that the coeliac plexus of the rabbit, cat, and dog contained small masses which were similar, both in their general histology and in their reaction to bichromate, to the cells of the adrenal medulla. Restating his results in 1899, he called these cell masses "the chromophil cells and bodies of the sympathetic."

Similar masses of like nature were subsequently reported to be present in the sympathetic chains and plexuses of many animals, including the human, so that in his classic paper of 1903 Kohn was able to cite more than a dozen papers concerned directly with the presence of extra-adrenal abdominal "chromaffin" tissue, as he preferred to call it. Because of the close connection between the chromaffin tissue and the sympathetic system, especially in their origin, Kohn proposed also the name paraganglion, a term which has been generally adopted, and also, as we shall see, probably much abused. To a particularly large mass of this tissue in the cat and rabbit, situated ventral to the aorta between the superior and inferior

mesenteric arteries, Kohn gave the name chief abdominal paraganglion (*das abdominale Hauptparaganglion*). Vincent ('10) from whose paper Figure 1 was taken, confirmed the presence of this latter body in many animals, and showed that it was essentially similar in histology to the adrenal medulla. Wislocki ('22), by the use of an improved technique for producing the chromaffin reaction, demonstrated its existence in several mammals in which Vincent had failed to find it.

In the human newborn and fetus, similar, but apparently always paired, masses were first demonstrated by Zuckerkandl ('01) in the aortic plexus at about the level of the inferior mesenteric artery. Although he described them under the term *Nebenorgane des Sympathicus*, and they are obviously the homolog, in a slightly different position, of the chief abdominal paraganglion, these bodies are now usually referred to as the "organs of Zuckerkandl." The organs of Zuckerkandl are apparently reduced in size, or lacking, in the adult. The chief abdominal paraganglion of Kohn is said to be absent also in the adult mouse, and usually in the adult rat. According to Goormatigh ('28), it is present in the newborn mouse, but subsequently breaks up into small masses which are distributed throughout the lower abdomen and pelvis.

Chromaffin bodies of macroscopic or microscopic size, or both, seem to have been reported in all mammals in which a careful search for them has been made. These paraganglia may vary from a few cells, or even single cells, usually adjacent to or imbedded in sympathetic ganglia and plexuses, to masses as large as 7 cm. in length and up to 5 mm. in width. The relative amount of this tissue outside the adrenal, as compared to that contained within the gland, has been variously estimated, with no real agreement. Kahn ('12) calculated that the mass of the chief abdominal paraganglion in the dog represented only about one-fourth to one-tenth that of both adrenal medullae; Wiesel ('06) went to the other extreme, in describing a paraganglion (not certainly identified since then) on the heart of the human, which, in itself, usually equalled or exceeded the combined mass of both adrenal medullae. Pearlman and Vincent ('19) suggested merely that the total mass of extra-adrenal chromaffin tissue may exceed that contained in the adrenal glands.

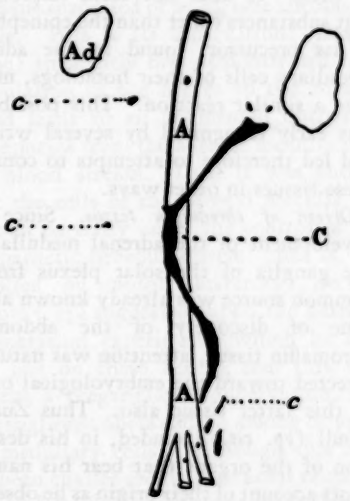

FIG. 1. DIAGRAM OF THE CHIEF ABDOMINAL PARAGANGLION, AND SEVERAL SMALLER CHROMAFFIN MASSES IN THE ABDOMEN OF AN ADULT DOG

A = aorta; Ad = adrenal; C = chief abdominal paraganglion; c = smaller chromaffin bodies. (Redrawn from Vincent, Fig. 1, p. 506.)

Some characteristics of chromaffin tissue

The chromaffin reaction. The earliest indications of the identity of these cell masses with the chromaffin cells of the adrenal medulla were, as we have seen, in part the general microscopic similarity

between the arrangements of the two tissues, but in much larger part the fact that both gave a similar reaction when treated with bichromate. Indeed, this reaction has remained one of the chief criteria. However, the reaction of the adrenal cells with potassium bichromate is said to be a relatively simple one (Ogata and Ogata, '17), probably depending upon the reduction of the bichromate to CrO_2. It does not seem improbable that substances other than the epinephrine or its precursor, found in the adrenal medullary cells or their homologs, might give a similar reaction. This possibility was early recognized by several writers, and led therefore to attempts to compare these tissues in other ways.

Origin of chromaffin tissue. Since the development of the adrenal medulla and the ganglia of the solar plexus from a common source was already known at the time of discovery of the abdominal chromaffin tissue, attention was naturally directed toward the embryological origin of this latter tissue also. Thus Zuckerkandl (*op. cit.*) included, in his description of the organs that bear his name, a short account of their origin as he observed it in the fetus. He described two types of cells arising from a common mass along the aorta; a small, dark-staining type which differentiated into nerve cells of the sympathetic ganglia, and a larger, pale-staining type which gave rise to the adrenal medulla and the *Nebenorgane* of the sympathetic. The *Nebenorgane* became disconnected from the adrenal medulla through the poorer development of their upper ends, only a few microscopic bodies persisting there. The lower ends enlarged, apparently up to term, to form the paired organs of Zuckerkandl.

Similar observations were made by Kohn ('03) on the origin of the chief aortic paraganglion and of the smaller chromaffin bodies in mammals other than the human. Indeed, the very term paraganglion implies a body of which the chief component differentiates from cells which are at one stage indistinguishable from those which are to form ganglion cells. Judged by this criterion, the so-called abdominal chromaffin bodies seem to be truly homologous with the similar cells of the adrenal medulla.

Effects of extracts. Following the discovery of Oliver and Schäfer in 1895, that extracts of the adrenal medulla produced rather typical effects upon the cardiac rhythm and blood pressure, an enormous literature has grown up about the subject of epinephrine and its physiological and pharmacological actions. It is not within the scope of this paper to summarize the findings and controversies in this field; the interested reader will find some discussion of this subject in reviews by Hoskins ('22) and Stewart ('24), and in numerous papers by Cannon and his coworkers. Regardless of these controversies, it seems to be well established that epinephrine, when injected in suitable doses into an intact animal, produces a fairly characteristic rise in blood pressure. Taking advantage of this basic finding, Biedl and Wiesel ('02) prepared extracts of the organs of Zuckerkandl from human fetuses and new-born, and showed that they produced effects quite similar to those of adrenal medullary extracts. The extracts on the whole were somewhat less powerful than those of the adrenal medulla, but resembled them qualitatively in every respect in which they were compared. As control extracts, prepared from retroperitoneal tissue in the neighborhood of the organs of Zuckerkandl, gave no such effects, Biedl and Wiesel felt no hesitancy in declaring that the adrenal medulla and the organs of Zuckerkandl were similar

endocrine organs, producing within their cells a similar chemical substance (adrenin, adrenaline, epinephrine).

The action of extracts of the abdominal chromaffin tissue (primarily of the chief abdominal paraganglion of Kohn) of mammals other than the human has been investigated by various workers (Vincent, '10; Kahn, '12; Fulk and Macleod, '16). They have reported results in agreement with the findings of Biedl and Wiesel on the organs of Zuckerkandl in the human. Vincent and Kahn both obtained typical effects upon blood pressure by injection of their extracts; Kahn used other physiological tests also (production of pupillary dilation in the frog, glycosuria in the rabbit), and, comparing the potency of extracts of adrenal medulla with those of the chief abdominal paraganglion, concluded that the latter contained from one-third to one-fourth as much epinephrine as did a similar weight of medulla. Fulk and Macleod, applying the most precise physiological tests known to them, found that their extracts (including also those from human material) gave effects qualitatively identical with those produced by epinephrine.

It must be admitted that this method of investigation of chromaffin tissue, the preparation of extracts and the determination of their pharmacological properties, is subject to various limitations. The small size of many of the groups of suspected chromaffin cells constitutes a major difficulty. It is obviously almost, if not quite, impossible to prepare extracts of tissue which can be located only in microscopic sections, and then frequently only after treatment with bichromate. For this reason, the tacitly accepted belief that the smaller chromaffin bodies also elaborate epinephrine is based upon their apparent homology with the larger groups of cells, rather than upon the experimental demonstration of this secretion. Some physiological evidence for this secretion, however, is found in the fact that tumors which apparently arise from this tissue may produce an elevation of blood pressure quite similar to that produced by tumors of the adrenal medulla (Howard and Barker, '37).

Nerve supply. In addition to these methods of investigation, there is one further criterion which may be applied to tissue suspected of being true chromaffin tissue. This is its innervation. Dreyer (1899) apparently first demonstrated that stimulation of the nerves to the adrenal gland leads to an augmented output of epinephrine from the adrenal medulla into the blood stream. Thus it was shown that the cells of the adrenal medulla are at least partially under the control of the sympathetic nervous system—that is, are supplied by motor (secretory) nerves. Elliott ('13) suggested, upon the basis of degeneration experiments which he carried out on these nerves, that this was largely a preganglionic innervation, the preganglionic fibers ending among or upon the medullary cells. Although this idea has been challenged by the casual observations of several workers (e.g. de Castro, '28, p. 370) Hoshi ('27) produced evidence in its support, and the recent experiments of Hollinshead ('36) and Swinyard ('37) seem to have established it upon a firm observational basis. This finding is also supported by the physiological experiments of Feldberg, Minz and Tsudzimura ('34) who showed that acetyl choline was released in the adrenal medulla following splanchnic nerve stimulation (acetyl choline is believed to be typically produced in the sympathetic system at preganglionic, but not at postganglionic, nerve endings).

While it perhaps cannot be maintained that no postganglionic nerve fibers end

upon medullary cells, the preponderance of preganglionic fibers is so overwhelming that there can be little doubt that this is the characteristic type of innervation of the adrenal medulla. It seems to follow from this that tissue which is otherwise identical with the adrenal medulla should have the same type of innervation. This has been shown to hold true both for the chief abdominal paraganglion of the cat and dog, and for at least some of the smaller masses more closely associated with the sympathetic chain (Hollinshead, '37).

This type of innervation, a direct one through preganglionic fibers, has been shown for no other type of tissue (unless the hypothalamico-hypophyseal tracts to the posterior lobe can also be regarded as preganglionic). Therefore, determination of the innervation of a tissue suspected of being chromaffin may throw considerable light upon its true nature. Well-chosen degeneration experiments are not so easily subject to misinterpretation as is the chromaffin reaction itself, and are more easily applicable to small masses of tissue than are experiments involving extraction methods.

To summarize the evidence for the true chromaffin nature of the so-called abdominal chromaffin bodies, we have, first, the appearance of an apparently true chromaffin reaction when treated with bichromate. The identity of this reaction with that given by the adrenal medulla apparently has never been challenged. Second, the embryology of these tissues is usually conceded to be similar to that of the adrenal medulla, though it must be confessed that proof of this, especially in the absence of experimental evidence, is difficult. Third, there is strong evidence that the chief abdominal paraganglion and the organs of Zuckerkandl contain a substance physiologically identical with epinephrine. Fourth, the innervation of the chief abdominal paraganglion and of at least some of the smaller masses of chromaffin tissue is similar to that of the adrenal medulla, and is different from that of all other types of tissue, so far as known.

Function of the abdominal chromaffin tissue

This question is inextricably bound up with the question of the function of the adrenal medulla. In the early days of investigation on the adrenal, when there was considerable question as to whether the medulla was necessary to life, death following adrenalectomy often was blamed upon removal of this part of the gland. It has been held that chromaffin tissue (the adrenal medulla usually being thought of) played a vital part in the maintenance of normal blood pressure, sugar metabolism, etc. Experiments such as those of Wislocki and Crowe ('24) in which animals remained healthy after destruction of the medulla of both adrenals and removal of the chief abdominal paraganglion, have indicated, however, that chromaffin tissue is not necessary to life. That it may play an important, but not a vital, rôle in the reactions of the animal has been shown by the experiments of Cannon and his co-workers (e.g. Cannon and de la Paz, '11; Cannon, '29). According to their concept, the release of epinephrine under conditions of excitement in the animal leads to a better preparation (increase in heart rate and blood pressure, mobilization of sugar, etc.) toward meeting the emergency which threatens. Under this interpretation, chromaffin tissue is thus thought of as playing a supporting rôle to the sympathetic nervous system, which, according to Cannon, is essentially an emergency mechanism.

To what extent these findings may be applied to the extra-adrenal chromaffin

tissue is not fully known. Since, however, this tissue receives an abundant innervation (Pines, '24; Hollinshead, '37), and since it and the venous blood leaving it (Kahn, *op. cit.*) have been shown to contain an active physiological principle, there can be little doubt that it also participates in the emergency reaction. It must be recalled, however, that the extra-adrenal chromaffin tissue is relatively best developed in newborn and young animals, and may undergo considerable apparent regression with age. According to Goormatigh's ('28) investigations on the mouse, the apparent regression in this animal is due largely to the breaking up and subsequent migration of parts of the larger chromaffin masses. Kohn ('03) and Palme ('34) regard regression of chromaffin tissue, beginning soon after birth, as being peculiar to the human. In this latter species, according to Zuckerkandl (*op. cit.*), there typically occurs considerable hyaline degeneration. It seems necessary to conclude, therefore, that the contribution of the extra-adrenal chromaffin tissue toward the total emergency reaction may vary much in different animals, or perhaps even in the same animal at different ages.

It might perhaps be recalled that there is considerable evidence (see, for example, Dale '38) that epinephrine or a physiologically identical substance is the usual transmitter of the nerve impulse between postganglionic sympathetic fibers and the end organs. The adrenal medulla and the abdominal chromaffin tissue thus stand in the same relation to preganglionic fibers as do the postganglionic neurons of the sympathetic system, and exert their effect upon the end organs through a similar or identical substance. Upon this basis alone, it would be hard to conceive of the function of chromaffin tissue in terms other than as an adjunct to the sympathetic.

THE COCCYGEAL BODY

This peculiar structure, located on the middle sacral artery or its branches, has occasionally been referred to as a chromaffin body. The observations of Stoerk ('07), and of von Schumacher ('08), have indicated that its constituent cells do not give the chromaffin reaction, and that it is not developed in relation to sympathetic ganglia. According to both these authors, the epithelioid cells in this body are probably hypertrophied elements of the media of the vessels. While there is apparently no direct physiological evidence concerning the function of this structure, there is nothing to indicate that it should be classed as a paraganglion or as chromaffin tissue. On the basis of its structure von Schumacher has interpreted it as an arterio-venous anastomosis between the middle sacral artery and vein.

THE CAROTID BODY

Stilling (*op. cit.*) included this organ among his "chromophil" bodies. Previous to that time it had been variously described as a misplaced ganglion of the sympathetic (intercarotid ganglion), as a glandular structure (intercarotid gland) and as a glomus. Kohn ('00) investigated both the morphology and embryology of this structure, and concluded that it arose in common with the anlage of the sympathetic ganglia (and thus was a paraganglion) and that its cells showed the chromaffin reaction. Both these conclusions have been challenged at various times, but it is to de Castro ('26, '28) that we owe the beginning of the development of our present conception of this organ.

In a careful investigation of the morphology and the nerve supply of the

carotid body, or, as he preferred to call it, the carotid glomus, de Castro produced rather convincing evidence that its cells did not give a true chromaffin reaction. He showed that the so-called chromaffin reaction here was probably not due to the presence of epinephrine, as denervation of the body produced no increase in the intensity of the reaction, and insulin shock produced no decrease in its intensity. He was unable to obtain the reaction with ferric chloride which also denotes the presence of epinephrine (Vulpian, 1856). He concluded that the apparent chromaffin reaction, which he described as differing somewhat from the true chromaffin reaction in appearance, was due to the richness of lipoids in some of the cells. De Castro's evidence has raised considerable doubt as to the specificity of the chromaffin reaction, and made the interpretation of an apparent reaction more uncertain. According to certain authors (e.g. Smith, '24; Boyd, '37) there are, however, some true chromaffin cells in the carotid body of ungulates, though the cells of this body as a whole do not show the reaction.

De Castro further showed that the carotid body receives primarily a sensory innervation through the glossopharyngeal nerve—an innervation which is hardly compatible with a belief in the chromaffin nature of this tissue. He suggested that, in view of the close relation between this body and the pressoreceptor area of the carotid artery (carotid sinus), the carotid body might have a somewhat similar function, but be concerned with the reception of chemical, rather than mechanical, stimuli from the blood stream.

Function of the carotid body

This conception of de Castro's has apparently been fully confirmed by recent physiological work. To summarize the evidence briefly, Heymans, Bouckaert and Dautreband ('30) and Schmidt ('32) have shown that the region of the carotid bifurcation, in addition to the already demonstrated sensitivity to pressure, is also sensitive to chemical stimuli, and that such stimuli may initiate important vascular and respiratory reflexes. This sensitivity of the carotid sinus region to anoxemia and other respiratory stimulants apparently accounts in part for the respiratory reflexes previously explained as due to direct chemical stimulation of the respiratory center. That the endings in the carotid sinus itself are not responsible for the chemical sensitivity is shown by the work of Bronk and Stella ('35) and Bogue and Stella ('35) in which, by recording the action currents in the nerve of Hering, they showed that the endings in the carotid sinus responded only to pressure changes, while the response to anoxemia and asphyxia persisted after denervation of the carotid sinus. Finally, Heymans and Bouckaert ('33) and Schmidt (*op. cit.*) have found that the response to chemical stimuli in the carotid region was abolished when the carotid body was experimentally excluded from the circulation, although the carotid sinus was still functional.

Effects of extracts. It is obvious that no discussion of the function of the carotid body can be adequate unless such findings as those just mentioned are taken into consideration. This has been clearly recognized by Boyd (*op. cit.*) and by Nonidez ('35b, '36a), who have accepted the carotid body as a primarily sensory structure. In some of the earlier literature, however, (for instance, the papers of Watzka, '30; Penitschka, '31; and Seto, '35) the function of the carotid body is discussed primarily from the standpoint of its supposed elaboration of a vasodepressor principle. While the source of this

theory of the secretory function of the carotid body is usually not given, it probably traces back to the work of Frugoni ('13), who described depressor effects from an extract of the bovine carotid body. Mulon ('04) had previously described pressor effects as following injection of an extract prepared from the carotid body of the horse. According to Christie ('33), Frugoni's experiments are open to serious question, as the effects reported followed only massive doses, and the extract was probably by no means derived only from the carotid body. Christie himself, however, in an apparently carefully controlled research, has obtained vasodepressor effects from an extract of a tumor of the human carotid body. Unfortunately, Christie was apparently not aware that a sensory innervation to this body had already been demonstrated, and has therefore failed to discuss his findings in the light of this knowledge. It is not yet clear what relation the presence of a depressor substance (if further work shall confirm it) may have to the already known functions of this body. It is hard to believe that the secretion of this principle constitutes a separate and important function of the carotid body, as Christie thought at that time. It would seem more probable that such a substance, if present, should rather participate in some way in the apparently proven chemoreceptor function of this organ. Further investigation of this subject is highly desirable, as it may throw additional light on the mechanism involved in the reception of stimuli by this body.

Origin of the carotid body

The facts which we have considered point to a sensory rather than to a true glandular function for the carotid body, and indicate that there is probably nothing in common, other than general arrangement of cells, between this body and the chromaffin bodies. From the embryological side, however, the evidence is not quite so clear. It seems to be granted by practically all investigators that cells do migrate from the cervical sympathetic ganglia, the ganglia of the ninth and tenth nerves, or from all of these, to the region of the carotid body. Opinion is sharply divided, however, as to the part these cells play in the formation of this structure. For instance, the origin of the carotid body has been attributed to sympathetic cells (Kohn, '00) or to the vagospinal ganglion (Benoit, '28). On the other hand, both Smith and Boyd (*op. cit.*) among others, have interpreted the contribution from ganglia of any type as a secondary one. Boyd has described it as making its appearance in the human, as a mesenchymal condensation about the internal carotid artery, before there is any evidence of the migration of cells of nervous origin. This latter he has seen in later stages of development; some of the migratory cells, he believes, become the ganglionic cells frequently found in and about the carotid body; some probably degenerate, while others may persist as small isolated cells which never develop the chromaffin reaction. Boyd denies the presence of cells of nervous origin in the whorls of epithelioid cells which constitute the parenchyma of the carotid body. Smith took an essentially similar view, but believed that the contribution from the ganglia in some species persists to form well-defined chromaffin tissue. She interpreted the carotid body as a complex of chromaffin and non-chromaffin portions, of which the latter is the essential portion of the gland, while the former varies much in different species.

The preponderance of evidence seems

to be against the idea of any fundamental relation between the carotid body and chromaffin tissue. While it is possible that true chromaffin tissue may exist in relation to this body in some species, it is evident that this plays no rôle in the function of the organ, for it is certainly absent in other species. From the functional standpoint, chromaffin tissue and the carotid body seem to be quite unrelated. The embryological evidence offered for or against the homology of the two should be interpreted with caution, as the difficulty of following the fate of specific cells in the region of the branchial arches must be considerable. Experimental evidence such as Stone ('29) has offered for the origin of the branchial cartilages from neural crest in the amphibia might go far toward settling this problem.

THE CARDIO-AORTIC BODIES

Under this heading may be grouped several epithelioid bodies, usually referred to as paraganglia, which are found in the supracardial and lower cervical regions of mammals. (Bodies of similar structure have also been found in corresponding positions in birds and reptiles —Nonidez, 35a; Muratori, '37; Palme, *op. cit.*) The literature concerning them is for the most part recent and relatively scanty, and it is indeed uncertain how many such structures are usually present in any one species. The accompanying figure (Fig. 2) from Boyd (*op. cit.*) shows the location of certain of these bodies in a human embryo.

The supracardial bodies

The first account of paraganglia in the region of the heart was apparently by Wiesel ('06), who reported the presence of a large mass of what he regarded as chromaffin tissue on the heart near the origin of the left coronary artery. It was this mass which Wiesel described as equaling or exceeding in bulk the combined medullae of the two adrenals, and which, according to Palme (*op. cit.*) has not certainly been identified since that time. Palme quotes Busacchi ('12) as having first recognized the existence of two distinct groups of paraganglia in this region in the human. The upper one lies between the aortic arch and the pulmonary artery, close to the ductus (ligamentum) Botalli, and was subsequently described by Penitschka (*op. cit.*) as the paraganglion supracardiale, and by Palme as the paraganglion supracardiale superius. Busacchi, Penitschka, and Palme have reported that this is essentially nonchromaffin in staining reaction, although Palme states that some chromaffin cells are apparently present in this body in early fetal stages. The second (lower)

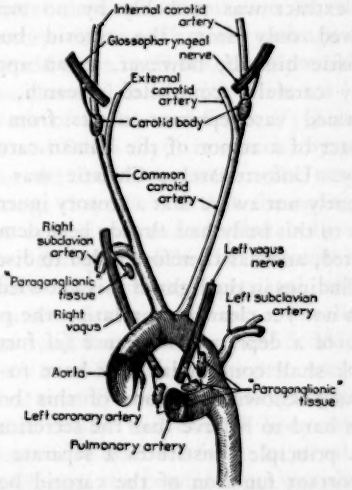

FIG. 2. THE BRANCHIAL ARCH REGION IN A 26 MM. HUMAN EMBRYO, TO SHOW THE POSITIONS OF THE SO-CALLED PARAGANGLIONIC TISSUE ASSOCIATED WITH THE NINTH AND TENTH CRANIAL NERVES
(From Boyd, Fig. 1, p. 27)

body lies between the pulmonary artery and the ascending aorta, close to the origin of the left coronary artery. According to Palme, this may represent the body reported by Wiesel, though it is much smaller in size. Busacchi apparently regarded this as chromaffin tissue. Palme, also, states that it is largely chromaffin in nature in the fetus, but that in the human adult it is much reduced in size and is represented only by small non-chromaffin groups of cells. These are apparently identical in structure with the paraganglion supracardiale superius. Palme has called this body the paraganglion supracardiale inferius. Seto (*op. cit.*) has described what is apparently the same structure in the adult human heart, and has reported that it is non-chromaffin in nature.

The structure of these bodies in mammals other than the human has been investigated especially by Palme (*op. cit.*), and by Nonidez ('36a, '37a). Their exact homology from one species to another is somewhat difficult to ascertain; however, Palme has found bodies in a corresponding position in the cat and rat, and has reported that the lower one is largely chromaffin in nature, the upper one, non-chromaffin. Nonidez ('36a) made no specific separation between the upper and lower paraganglionic masses in the cat, describing them rather as "irregular masses of rounded epithelioid cells extending from the arch of the aorta to the base of the heart" (p. 215); in a previous paper (Nonidez, '35b; Fig. 1) he has illustrated a similar condition for the rabbit. In the cat, certain of the cells after formol-bichromate fixation contained yellowish granules. Nonidez suggests the possibility that these may be similar to the cells described by de Castro in the carotid glomus of this animal. Nonidez ('37a) has stated that the position of the two groups in the dog rather closely approximates that in the human, but has reported no observations on these bodies after bichromate fixation.

The aortic bodies

In addition to these epithelioid groups below the arch of the aorta, Nonidez ('35b, '37a) and Muratori ('34, '35) have also described similar bodies above the arch. For these Nonidez ('35b) has suggested the term aortic glomi. They vary somewhat in position, but are usually more or less closely related to the origins of the left and right subclavian arteries, respectively. They apparently are represented in Boyd's figure of the human embryo by the upper masses attached to the two vagus nerves. Tschernjachiwsky ('38) also has reported their presence in the human embryo and infant. According to Nonidez, who has made a very careful investigation of their structure and innervation in the rabbit, cat, guinea pig and dog, they are essentially non-chromaffin in nature, though in the cat certain cells contain fine yellow granules after treatment with bichromate. These are apparently identical with the similar cells in the supracardial paraganglia of this animal.

Aside from the presence of chromaffin cells in the cardio-aortic paraganglia, all the investigators who have studied them agree that they are essentially alike in structure, and in turn closely resemble the carotid body. In the fetus and newborn they may be fairly compact structures located in general along the vagus nerves, and composed of cords or whorls of epithelioid cells which receive a very rich blood supply, usually by a direct branch from the aorta, pulmonary artery, or subclavian artery. In older individuals the balls of epithelioid cells originally forming one fairly distinct mass may be

separated from each other by considerable fat and connective tissue. Small groups of these cells may also be embedded entirely in a nerve trunk (Palme) or in the wall of the aorta or pulmonary artery (Nonidez, Palme).

Nerve supply

Beginning with the work of Penitschka, the writers who have discussed these structures have all pointed out the close relation of these bodies to the vagus nerves, though their actual innervation has been investigated in only a few cases. Palme described fine nerve fibers penetrating the cell groups of the supracardial paraganglia, but left the question of their intimate relation to the cells unsettled. Seto (*op. cit.*) on human material (probably the inferior supracardial paraganglion) described fine fibers, of apparent vagus origin, as ending among the parenchymal cells in a "nervous terminal reticulum"; these he regarded as motor fibers. Nonidez, in his very careful series of studies on the innervation of the bodies above and below the aortic arch in several animals, has also described the fibers as definitely of vagus origin. According to his findings, however, they end freely among the cells, often with small loops or terminal swellings. Tschernjachiwsky (*op. cit.*) has reported similar findings in the human. Nonidez has not found a nervous terminal reticulum in his own preparations, prepared by a different technique than that used by Seto, nor apparently has Muratori ('37) found such a structure. Nonidez has recently presented evidence in another series of papers ('36b, '37b), based upon comparison of tissues stained for reticular tissue and for nerve fibers, that the so-called nervous terminal reticulum is probably composed in reality of fine argyrophil connective tissue fibers. This criticism is of some importance in the present instance, as it is apparently largely upon the presence of this terminal reticulum that Seto bases his belief that the fibers among the parenchymal cells are motor. Nonidez has interpreted the fibers as sensory, as they are derived, according to his findings, largely from medium-sized or large fibers. Recent degeneration experiments (Hollinshead, '39) have indicated that the nerve fibers in the aortic glomi of the cat arise from cells situated in the ganglion nodosum of the vagus, thus supporting Nonidez' interpretation of their sensory character. Degeneration experiments upon the nerve supply to the bodies below the arch of the aorta have apparently not yet been carried out; it would be rather surprising, however, in view of the apparently identical nature of these bodies with the aortic glomi, if they should prove to have a different type of innervation.

Function of the cardio-aortic bodies

Penitschka, Palme, Muratori, Seto and Nonidez have all pointed out that these bodies are especially related to the pressoreceptor zones on the great vessels near the heart, just as the carotid body is related to the pressoreceptor area of the carotid artery. The last three workers have also described nerve endings of the pressoreceptor type in the vessels to or in the cardio-aortic bodies, as has also Tschernjachiwsky. In so far as these are concerned it seems probable, therefore, that these bodies (or more properly speaking, their vessels) may function as accessory vasodepressor areas. However, this does not explain the function of the parenchyma of these bodies, nor the meaning of the nerve endings among the parenchymal cells. Concerning these matters there have been several tentative opinions ventured. Penitschka suggested merely that these bodies were similar in

function to the carotid body, and probably secreted a vasodepressor substance. Palme was unwilling to grant that they are endocrine glands in the usual sense of discharging a secretion into the vascular system; instead he suggested that "die paraganglionären Zellen Wirkstoffe an die umgebend Nervenfasern abgeben dürften, die den Zustand, vielleicht die Erregungsfähigkeit der betreffenden Nerven örtlich beeinflussen könnten" (p. 419). Seto interpreted the body which he investigated as an endocrine organ, liberating a vasodepressor substance into the blood stream, and representing an *Erfolgsorgan* for the aortic reflex. Muratori ('37) states merely that these structures probably have something to do with the regulation of blood pressure. Nonidez, reviewing their similarity to the carotid body (emphasized by all these investigators), and also the recent literature apparently demonstrating a chemoreceptor function for the carotid body, very logically suggested that the cardio-aortic bodies are also chemoreceptors. This view has also been accepted by Boyd and Tschernjachiwsky. For the present the matter rests here, as there seem to be as yet no physiological experiments bearing directly on this question. Boyd (*op. cit.*, p. 29) has called attention to the fact that the residual sensitivity to anoxemia remaining after section of the nerve of Hering, but disappearing after section of the vagi, may be explained by this supposed function of the cardio-aortic bodies.

Chromaffin tissue in the cardiac region

If we turn now to the presence of chromaffin tissue in the cardiac region, we find relatively little information concerning it. There seems to be no reason why such tissue should not be present in this region, in connection with sympathetic plexuses; according to the reports of Palme on the human, and of both Palme and Pannier ('35) on the cat, there are collections of true chromaffin cells here. It may be recalled that Palme described the paraganglion supracardiale inferius as being composed in large part of chromaffin tissue, though he distinguished a non-chromaffin portion from this. The fact that the two tissues may perhaps occur in close apposition to each other should not be interpreted to mean that there is either a functional or close genetic connection between the two. The term cardio-aortic bodies, as here used, is limited to the non-chromaffin masses of epithelioid cells; the chromaffin masses, when present, presumably differ in no way from the similar masses in other locations.

ARE THE CAROTID AND CARDIO-AORTIC BODIES PARAGANGLIA?

The whole weight of evidence concerning the cardio-aortic bodies seems to be that they are non-chromaffin in nature, and that they are identical in structure with the carotid body. It seems reasonable to believe that the carotid body and the cardio-aortic bodies are homologous structures which are also similar in function, and can therefore be fairly discussed as a group. The question then arises as to whether these structures can properly be termed paraganglia. In the minds of most of us, probably, this term implies an endocrine organ composed of chromaffin tissue, as that was the original use of the word. Recently however, in the articles from Kohn's laboratory on the supracardial paraganglia (Penitschka, Palme, Seto, Watzka) a distinction has been made between chromaffin and non-chromaffin paraganglia. The former are distinguished by the chromaffin reaction, the presence in their cells of a vasopressor substance (epinephrine), and their innervation through the sympathetic; a

further criterion, applicable only to the human, is that this type undergoes a rapid regression which begins soon after birth. The second type (composed of the carotid and cardio-aortic bodies) is non-chromaffin, is believed by that school to contain (and secrete—Seto) a vaso-depressor substance, and to be innervated through cranial nerves alone, or through both cranial nerves and the sympathetic. The bodies of this type apparently persist in well-developed form throughout life. The two types are frequently fairly separate, but there may (Palme) be considerable admixture of the two. Both types are believed by this school of thought to arise in common with the peripheral ganglionic elements of the nervous system. It appears, therefore, that these two types of tissue are grouped together as paraganglia because of their supposed endocrine natures, their intimate relations to the peripheral nervous system, and their supposed origins from similar elements. On the other hand, they are separated by their reactions to bichromate, and by the differing effects of their extracts.

If these supposed likenesses could be proven, there would certainly be excellent reasons for calling both types of tissue paraganglia. As we have seen, however, the best evidence is against the essentially endocrine nature of the non-chromaffin bodies. Corresponding with this apparently sharp difference in function, their relation to the peripheral nervous system, while perhaps superficially similar, really differs markedly: the chromaffin bodies are related to motor fibers, the non-chromaffin apparently to sensory fibers. The only real linkage between the two groups seems therefore to be their supposed origin from the nervous system. This latter has also been questioned; even if it were proven, the advisability of imposing the same name upon two such different tissues, simply because they are homologous, might well be doubted. One cannot very well argue with Kohn concerning the usage of the term which he devised; however, it would seem more reasonable to restrict the term paraganglion to neurogenic endocrine organs which seem to be physiologically, as well as embryologically, the equivalent of autonomic postganglionic neurons. The only known example of this today is chromaffin tissue. For the non-chromaffin bodies, especially in the present state of our knowledge, terms such as aortic glomus and carotid glomus, which suggest merely the intimate association between the blood stream and these bodies, or the still more neutral terms carotid body, aortic bodies, etc., seem to be preferable.

THE ABDOMINAL VAGAL PARAGANGLIA

These are small epithelioid bodies described by Goormatigh ('36) along the course of the vagus nerves in the abdomen of the mouse. According to him they are non-chromaffin in nature; he suggests that they may be a parasympathetic homolog of the (sympathetic) chromaffin tissue, and represent secretory organs for the liberation of some substance akin to acetyl choline. Goormatigh has not demonstrated an innervation to these bodies, although his theory demands that they be supplied with motor fibers from the vagus. Until such a demonstration has been made, or until other evidence as to the presence and function of these bodies has been obtained, it seems fruitless to discuss these structures further. It might be added, however, that if Goormatigh's hypothesis concerning the nature of these bodies should prove to be true, they should certainly be termed paraganglia; we would then have two types, sympathetic and parasympathetic

paraganglia, each corresponding in certain important physiological respects to the postganglionic neurons of the system of which they are a part.

SUMMARY

We have seen that the status of the so-called abdominal chromaffin tissue is rather clearly defined. It is generally accepted as being true chromaffin tissue, with the ability to secrete epinephrine. Although the concept of the nervous origin of the adrenal medulla has been bitterly contested by a few workers, it is on the whole generally conceded, and the argument seems equally strong for a similar origin of the extra-adrenal chromaffin tissue. These two tissues seem to be similar both in origin and in function, and to correspond to the original meaning of the word paraganglion. On the other hand, the carotid and cardio-aortic bodies are non-chromaffin in nature, and apparently represent, as Nonidez ('37a, p. 311) says, "complex neurovascular structures intimately associated with the branchial arches of the embryo." They are presumably sensory in function, probably representing receptors sensitive to chemical changes in the blood, through which vascular and respiratory reflexes are initiated. Their neurogenic origin has not been proven, and the propriety of terming them paraganglia may well be questioned.

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ADDENDUM

Since this was written, the following reviews have appeared:

HEYMANS, C. and J. J. BOUCKAERT. 1939. Les chémo-récepteurs du Sinus Carotidien. Ergebn. d. Physiol. Bd. 41, S. 28–55.

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APPLICATION OF HIGH-FREQUENCY ELECTROSTATIC FIELDS IN AGRICULTURE

By P. A. ARK

Division of Plant Pathology, Department of Agriculture, University of California, Berkeley, Calif.

AND

WILLET PARRY

Technician in Electrical Engineering, University of California

INTRODUCTION

IN RECENT years studies on phenomena accompanying an application of high-frequency currents to biologic materials, such as bacteria, insect pests, etc. have been made. The term "a high-frequency-electrostatic-field" refers to the field between two electrodes of some form which is subject to a periodic charge and discharge by an oscillating electric circuit.

Physics involved in the phenomenon are extremely complex. Matter is considered, in the light of modern physics, as made up of electricity or conversely, that electricity is the fundamental basis of matter. Any kind of matter, a book, a table, or a living body, is, in the final analyses, an assemblage of electrons and protons associated with a quantity of energy proportional to the mass of the body. Furthermore, every particle of matter in constant vibration has a definite frequency. Biologists are always eager to test the effect of various physical factors on biologic material whenever that factor is subject to laboratory handling. Thus, much work has already been done on the action of various types of radiant energy such as gamma, X- and Roentgen rays (1, 13, 20, 22, 50, 55, 61, 81, 167, 168, 169, 170, 171, 172, 182, 222, 227), radium emanation (111, 112, 175, 176, 179), ultra-violet rays, visible light spectrum and infra-red light (46, 50, 57) on living things.

Studies of the so-called ultra-sonic waves, in relation to the effect of that type of radiation on living matter, have yielded very interesting results (15, 19, 29, 30, 31, 47, 48, 65, 66, 67, 68, 69, 70, 71, 79, 94, 117, 147, 154, 155, 166, 186, 198, 199, 200, 208, 216, 228, 229, 230, 231, 232, 233). An application of this type of energy was recently made (85) to increase the yield of potato and pea crops. An average increase of 16.7 per cent in yield was observed on potato tubers sonized by 4×10^5 cycles per second. Pea seeds treated by ultra-sonic waves showed increased germination, earlier blooming, and were noticeably more vigorous than the controls. Although the peroxidase activity increased, the activity of catalase decreased as a result of applying ultra-sonic waves.

Recently biologists have become interested in the type of radiation used in radio transmission, commonly known as Hertzian waves. This includes long, short, and ultra-short radio waves. The short and ultra-short radio waves are situated between the extreme infra-red and long radio waves in the electro-magnetic spectrum. It is customary to classify radio waves as long when they range from 200 meters or more, as short when they are

from 10 meters to 200 and from 10 down as ultra-short.

With the improvement of the short-wave-vacuum-tube-radio-oscillator for obtaining high-frequency waves, it soon became possible to utilize high-frequency electrostatic fields in biological research (40, 123, 125, 157, 162, 163, 180, 221).

The equipment now used by investigators is constructed on the principle of a short-wave radio transmitter in which the output of the oscillating tubes is concentrated between two aluminum or copper plates coupled to the oscillating circuit of an oscillating tube (Fig. 1).

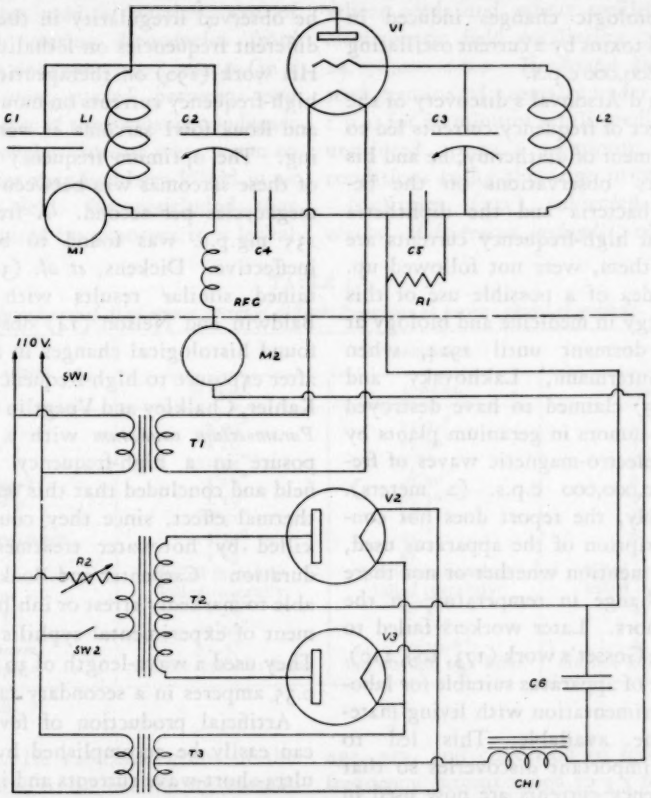

FIG. 1. THE HIGH-FREQUENCY GENERATOR AND POWER SUPPLY

C1 Exposure condenser, consisting of two aluminum plates
C2 Variable condenser (transmitting type)
C3 Variable condenser (receiving type)
C4 Fixed condenser
C5 Fixed condenser
C6 Filter condenser
R1 Resistor
R2 Variable resistor
M1 Thermo-couple radio-frequency ammeter
M2 Milliammeter dc
T1 Power transformer
T2 Filament transformer
T3 Filament transformer
CH1 Smoothing choke
SW1 Filament and main line switch
SW2 High voltage power switch
V1 Type 852 (RCA)

In 1893, d'Arsonval (7, 8) observed a

rise in temperature and increased metabolism in small laboratory animals when they were exposed to high-frequency currents. Later he and his assistants (9, 10, 11) reported additional observations on biologic changes induced in bacteria and toxins by a current oscillating at a rate of 800,000 c.p.s.

Although d'Arsonval's discovery of the thermal effect of frequency currents led to the development of diathermy, he and his collaborators' observations on the behavior of bacteria and the diphtheria toxin, when high-frequency currents are applied to them, were not followed up. Thus the idea of a possible use of this type of energy in medicine and biology at large lay dormant until 1924, when Gosset, Gutermann, Lakhovsky and Magrou (59) claimed to have destroyed crown gall tumors in geranium plants by the use of electro-magnetic waves of frequency 150,000,000 c.p.s. (2 meters). Unfortunately, the report does not contain a description of the apparatus used, nor does it mention whether or not there was any change in temperature in the treated tumors. Later workers failed to corroborate Gosset's work (173, 209, 210). Soon a type of apparatus suitable for laboratory experimentation with living material became available. This led to numerous, important discoveries so that radio-frequency currents are now used in biological and chemical research, medicine, and to some extent in agriculture (32, 34, 40, 141, 146, 196).

The purpose of this paper is to review most of the literature pertaining to the effects of high-frequency oscillating fields.

EFFECT OF OSCILLATING ELECTROSTATIC FIELDS ON MEN AND ANIMALS

Small laboratory animals and men exposed to high-frequency field were found to respond to it by rise of body temperature. Thus, Schereschewsky (187, 190) noticed that temperature of mice increased when they were placed between the plates (electrodes), particularly at certain frequencies. In his experiments he observed irregularity in the effects of different frequencies on lethality to mice. His work (190) on therapeutic effects of high-frequency currents on mouse sarcoma and Rous fowl sarcoma is very interesting. The optimum frequency in the case of these sarcomas was between 66 and 68 megacycles per second. A frequency of 135 mg.p.s. was found to be entirely ineffective. Dickens, *et al.* (38, 39) obtained similar results with sarcoma. Baldwin and Nelson (14) observed profound histological changes in albino rats after exposure to high-frequency currents. Kahler, Chalkley and Voegtlin (97) killed *Paramoecium caudatum* with a short exposure in a high-frequency oscillating field and concluded that this was purely a thermal effect, since they could also be killed by hot-water treatment of like duration. Carpenter and Boak (24) were able to markedly arrest or inhibit development of experimental syphilis in rabbits. They used a wave-length of 30 meters and 0.35 amperes in a secondary tank circuit.

Artificial production of fever in man can easily be accomplished by means of ultra-short-wave currents and is employed as a therapeutic means, as shown by Carpenter, Boak and Page (25). Graham and Fabian (62) studied the effect of high-frequency currents on many different animal species (cf. Table 1).

EFFECT ON INSECTS

The effect produced by high-frequency currents on insects is obviously of great economic importance. Studies on this subject conducted since 1929 indicate that Hertzian waves can be and actually are

utilized in eliminating such pests as bean weevils and flour moths.

Headlee (73, 74, 75, 76, 77, 78) has studied the effect of high-frequency currents on insects since 1928. In his experiments Headlee used a Hartley type of circuit (77), testing frequencies from 750,000 to 14,000,000 c.p.s. Insects (in a test tube) were placed between two aluminum plates of the exposure condenser for time intervals. Insects were warm to the touch after they had been killed in an electrostatic field. He concluded that death was caused by exposure to a lethal temperature. He subjected grubs of the Japanese beetle to an oscillating current of 3,000,000 c.p.s., with voltage gradients between plates 4,000 $\frac{\text{volt}}{\text{inch}}$ and 5985 $\frac{\text{volt}}{\text{inch}}$. [Voltage gradient is determined by the formula $V\left(\frac{\text{volt}}{\text{cm.}}\right) = \frac{6000 \times I \times \lambda}{S^2}$ (35), where I is in amperes, λ in meters, and S in centimeters and is the area of the condenser plates]. Grubs died in 90 to 180 seconds with the first gradient and in 60 to 120 seconds with the second gradient. Because of the higher voltage gradient in the second case the temperature was correspondingly higher, and therefore, grubs died sooner. Headlee (73, 76) tested the effect of radiation, which had proved lethal to insects, on plants by subjecting wheat seeds and wheat seedlings to an electrostatic field oscillating 750,000 to 14,778,000 c.p.s. He found that wheat seed germinated normally under 3,000,000 c.p.s. for 80 minutes while seedlings were uninjured up to a 10-minute exposure, conditions being the same in both cases.

McKinley (122) subjected parasitic wasps, *Habrobracon juglandis*, of different age, sex, and condition of feeding to a frequency current tuned to 3.5 meters and having 1.8 amperes in the auxilliary circuit. The wasps were killed in an average time of 11.41 seconds. In another experiment (121), he determined that the lethal time for Golden Bantam corn was from 5 to 60 minutes. Corn seeds exposed for from 30 to 40 seconds were definitely stimulated. Hadjinicolau (64) was successful in killing adults, larvae and pupae of insects feeding on stored products. Larvae of *Plodia interpunctella* affecting dry figs, apricots, etc., and larvae and pupae of

TABLE 1

The influence of displacement current of different frequencies on various species of animals

NAME OF ANIMAL	FREQUENCY		
	10 mg.p.s.	15 mg.p.s.	7.5 mg.p.s.
Mus musculus	2′09″	31′03″	45′*
Passer domesticus	1′20″	17′40″	45′*
Perca flavescens	12′44″	45′*	45′*
Cambarus americanus	3′26″	28′30″	45′*
Thamnophis sirtalis	2′19″	25′36″	45′*
Musca domestica	6′51″	45′*	45′*
Melanoplus femur-rubrum	5′29″	45′*	45′*
Aphid mellifica	1′29″	45′*	45′*
Samia cecropia	killed instantly	killed instantly	killed instantly
Anosia plexippus	killed instantly	killed instantly	killed instantly
Lumbricus terrestris	2′24″	26′36″	45′*
Rana virescens	3′20″	34′39″	45′*
Ambrystoma tigrinum	32.5″	20′36.6″	45′*
Graptemys geographia	did not kill in 1 hour	did not kill in 1 hour	did not kill in 1 hour

* Did not kill.

Sitrodrejea panicea affecting ground pepper were killed when irradiated for a period of time ranging from 2 to 2.5 minutes, frequency being 1,090,000 c.p.s. and a field strength of 3,977.6 $\frac{\text{volt}}{\text{inch}}$. All stages of the bean weevil are killed, without harming the seed, with a field strength of 4000 $\frac{\text{volt}}{\text{inch}}$. Vishniakova (226) found that humidity of the seed is an important factor in lethality of high-frequency currents. Temperature of the seed fluctuated from 33 to 66°C., depending upon wave-length, voltage gradient, and water content, when a lethal dose was employed. From her experiments she concluded that the most useful wave-length of any condition of seed is six meters. She also found that lethal time for pupae and adults of the bean weevil was the same, while larvae and eggs required longer exposures. Thus, with a voltage gradient of 5080 $\frac{\text{volt}}{\text{cm}^2}$, they perished in 18 seconds, while with a gradient of 7000 $\frac{\text{volt}}{\text{cm}^2}$ it requires 6 to 8 seconds. Mites are more resistant than weevils. They require higher gradients and longer exposures. With a voltage gradient 8000 $\frac{\text{volt}}{\text{cm}^2}$ and a wave-length of 5 meters they perished in 2 minutes. Later, however, she found that they were killed with the same exposure as bean weevils when surrounded by seed. Experiments of Vishniakova (226) showed that the fall in germination for any voltage gradient depends on the time of exposure and it requires longer exposures than those for killing insects. A fall in germination coincides with a temperature of 50° to 60°C. within exposed seed. The killing time for insects was considerably lower when they were exposed in a layer from 1.5 to 3 cms. thick.

Andreiev and Balkashin (3) used apparatus with a range of from 8 to 40 meters, with a field strength of 3500 volts in a primary circuit, and with plates 12 cms. x 15 cms. separated 2.5 cms. Their material consisted of wheat seed and the following mites: *Aleurodus farinae* Degeer., *Clyciphagus cadaverum* Schr., *Tyroglyphus longior*, and *Cheriletus eruditus*. Wheat seeds weighing 40 grams and artificially infested with the mites were placed in small paper troughs (6 cms. x 3 cms.). After each exposure, the seeds were examined, and from each lot was taken a sample of 200 seeds in order to determine the effect of treatment on germination. The remaining seeds were placed in both a dry jar and a jar with moist filter paper and observed for four days. Two controls were included in each test: one in which wheat infested with mites was placed in a dry jar, and the other, in which infested wheat was placed on slightly moistened filter paper in jars. It was observed that the temperature of irradiated seed registered 40° to 70°C., and, in some cases, even higher. The mites were killed in a shorter time under a shorter wave. Under a wave-length of 40 meters mites were killed in 5 minutes, while below 11 meters, they perished in 30 seconds. When seeds were exposed for 1 to 2 minutes, germination was considerably lower. Short exposures (from 15 to 25 seconds) did not seriously affect the seed. It is concluded that insects may be killed in a fraction of a second if the field strength is increased.

Very interesting dependence of lethal dosage on voltage gradient and wave-length is presented by Evreinov (42, 43). All the stages of bean weevil and mites were killed with voltage gradients ranging from 5000 to 7000 $\frac{\text{volt}}{\text{cm}^2}$ and wave-lengths from 5 to 7 meters in from 4.8 to

6 seconds. The temperature of the seeds was below 50°C. At a wave-length of 5 meters and a voltage gradient of 6500 $\frac{\text{volt}}{\text{cm}^2}$ (at 53°C.), the lethal time for bean weevils was 2.4 seconds. Lethal action for weevils begins at a voltage gradient of 2000 to 3000 $\frac{\text{volt}}{\text{cm}^2}$. Below a voltage gradient of 2000 $\frac{\text{volt}}{\text{cm}^2}$, the time of exposure may be increased as long as desired without injuring bean weevils. Evreinov and other investigators maintained that the shorter the wave-length, the shorter the lethal time. A small change in a voltage gradient leads to considerable change in an exposure time. If a voltage gradient between 2000 to 3000 $\frac{\text{volt}}{\text{cm}^2}$ is changed approximately 20 to 25 per cent, a lethal dose may change some 200 to 300 per cent. A lethal dose falls rapidly with an increase in thickness of the exposed seed. Moisture content of seed changes a lethal dose and affects the characteristics of apparatus.

In 1933, Davis (34) published a semi-popular account of his investigations on the effect on some materials of 30 and 6 meter wave-lengths from a 20 kilowatt generator. He stated that the 30 meter low-capacity waves were effective in exterminating adult insects in small quantities of wheat within a period of about 90 seconds, but later the eggs hatched. With the 20 kilowatt and 6 meter waves, an exposure of 6 seconds proved lethal to eggs, larvae and adults. His observations on treated materials extended over a period of several months. He observed no injury to the seed. In some cases, an increase in the germinating power of seed (stimulation) occurred.

EFFECT OF AN OSCILLATING ELECTROSTATIC FIELD ON BACTERIA AND FUNGI

The action of electrostatic fields induced by high, or ultra-high, frequencies on bacteria, fungi, and toxins is of considerable interest. As has already been mentioned, d'Arsonval *et al.* noticed some changes in bacteria and diphtheria toxin as early as 1893.

In 1930, Mellon, Szymanowski and Hicks (142) studied the effects of oscillating currents on diphtheria toxin when the temperature-induced effect on material was eliminated. In order to maintain a low temperature level, the toxin was chilled to 7°C., and subsequently treated for 4 minutes with a current until the sum total of minutes of exposure varied from 15 to 60. Control samples were given alternate treatments with ice and hot water at comparable exposures. In another experiment on cooling, a benzol cooler was used. In both tests they reported a definite attenuation of diphtheria toxin, while the temperature attained in the control samples did not affect the toxin.

Haase and Schliephake (63), working with tubercle bacillus (*B. tuberculosis*) and *Staphylococcus* sp., noticed that *B. tuberculosis* treated for 30 seconds by high-frequency currents showed retardation of growth from 14 to 24 days after subculturing and staphylococci died more quickly than control cultures similarly exposed in a water bath. With a somewhat complicated arrangement for cooling biologic material undergoing high-frequency current treatments (plate circuit 3000 volts d.c., wave-length from 1.9 to 3.7 meters, and voltage across the plates from 200 to 300 volts) Szymanowsky and Hicks (215) obtained a definite attenuation of the three major bacterial toxins, diphtheria, tetanus, and botulinus in raw broth filtrates. The temperatures ob-

tained in treated solutions did not cause any change in the toxins.

Bacteria can be killed by high-frequency currents, depending upon conditions of the experiment. Fabian and Graham (44), placing bacteria (*B. coli*) in a line of force of high-frequency electrostatic fields found that with a displacement current of 0.8 amperes (secondary winding of transformer delivered 2000 volts) at a frequency of 7.5 mg.p.s., bacteria increased very rapidly. After 10 minutes' treatment the temperature effect was noticeable. At 10 mg.p.s. the temperature began to rise quickly and the number of organisms rapidly decreased. This frequency appeared to be the most effective in killing bacteria. When the temperature of the broth containing bacteria was maintained between 17° and 19°C., "a frequency of 10 mg.p.s. is the most effective in killing bacteria, with 15 megacycles per second the second most effective, and 7.5 megacycles per second the least effective."

Tverskoi (223) studied the behavior of *Erwinia carotovora* in high-frequency electrostatic fields. He suspended the bacteria in a 0.01 per cent NaCl solution and then placed them between condenser plates having a circuit tuned to 15.5 and 10 meters. After this treatment the slanted agar medium was inoculated and incubated at 28° to 30°C. Under conditions of the experiment, it appeared that a wave-length of 10.4 meters was most effective. The growth of the organism was retarded after 2 minutes of treatment, while killing occurred in 2.5 to 3 minutes. He showed that density of the suspension and the time factor were independent as related to killing of the organisms. Bacteria on a glass slide were inhibited in growth after treatment at 5.6 meters for 2 minutes and were dead after 5 minutes. However, bacteria on a dried silk thread were not killed even after 30 minutes exposure.

Extremely short waves (27 to 45 cms.) have recently been tried on bacteria and fungi by Gier (57). Bacteria (*Ph. vesicatorium*) were killed at the frequency of 35 cms. when exposed for 24 hours or longer. No effect was observed with other wave-lengths on *Actinomyces scabies*, *Saccharomyces* spp., *Alternaria solani*, *Cephalosporium* sp., *Diplodia zeae*, and *Gibberella saubinetti*. Species of *Collybdia dryophila* Fr., *Sclerotium bataticola* Taub., and *Fusarium batatis* Wr. were used by Johnson (95) in his work on the effect of Hertzian waves on fungi. His apparatus was not described although he mentioned the wave-lengths employed (50 and 100 meters). In his words, "there was no effect on 3 and 4 day cultures of *Fusarium batatis*, on 4 to 8 day cultures of *Collybdia dryophila*, on 3 to 4 day old cultures of *Sclerotinia bataticola* as a result of constant irradiation for 65 hours by a wave-length of 100 m. and for 48 hours by a wave-length of 50 m."

Tverskoi (223, 224) found that wave-lengths of 20 and 30 meters were unsatisfactory even with very long exposures. Irradiation with 10.4 meters and less was effective. *Fusarium solani*, *Sclerotinia libertiana*, *Botrytis cinerea* and *Phytophthora infestans* were tested with wave-lengths of 5.6 to 10.4 meters. The effect on fungi began at 10.4 meters, but longer exposures were required. Thus, *F. solani* was inhibited in growth after 10 minutes' exposure. With an increase in field strength, the inhibition time was shortened. For instance, when the distance between the plates was 2.5 cms. instead of 3 cms. at 9 meters wave-length, inhibition for growth of *F. solani* began after 5 minutes' treatment; after 10 minutes the organism was killed. The most effective wave-length appeared to be 5.6 meters.

A one-minute treatment inhibited fungus growth, while exposures from 4 to 6 minutes were lethal. Suspensions of sporangia of *Phytophthora infestans* in saline solution were inhibited after two minutes' treatment between the condenser plates at a temperature of 31° C. and were killed after 3 minutes or more at temperatures of 37° to 41° C. Tverskoi subjected fungi to treatment in a water bath with temperatures corresponding to those obtained between the condenser plates. When *Fusarium solani* was immersed in a water bath at 45° C. and held for 10.5 minutes, there was no effect. However, a temperature of 50° C. for 30 minutes was lethal to the fungus. Yet, in a high-frequency electrostatic field, fungi were killed in 5 minutes when the temperature of the medium reached 50° C.

Wood destroying fungi, *Merulius lacrymans* Schm. and *Poria vaporaria* Pers., were found to be susceptible to ultra-short waves. Imshenetzki (84) found that these fungi may be killed in 45 to 60 minutes in a comparatively weak electrostatic field. He used a generator of 500 watt dissipation, 3000 volts on anode, and 4.2 to 4.8 amperes in a secondary tank circuit. Power between the plates was equal to 504.10^8 ergs. Cultures were irradiated 4 and sometimes 8 meters. The time of exposure varied from 1 to 92 minutes. Experiments were first made with pure cultures and then with wood parasitized by these fungi. Pure cultures of fungi were killed after 60 minutes in a field of 500 volts. *Merulius lacrymans* was killed in 30 minutes. When the strength of a field was 50 volts the fungi could not be killed even after a 2-hour exposure. It was found that wood does not hinder ultra-short waves and that fungi in wood may be killed in from 45 to 60 minutes. Shorter waves shorten the lethal dose: *Merulius lacrymans*, under a wave-length of 8 meters, was killed in 60 minutes, while under 4.5 meters a lethal dose was 50 minutes when the fungus was within or on the surface of wood. The position of a wooden block in a condenser does not affect the sterilizing action of ultra-short waves.

Interesting behavior in a high-frequency electrostatic field was reported by Metlitzky and Soboleva (143) for *Sclerotinia libertiana* and *Botrytis cinerea*. Exposed between plates of 12 cms. diameter, field strength 2000 volts, 5.5 amperes in a secondary tank circuit, and a wave-length of 2.2 meters, these fungi were unaffected by exposures from 1 second to 30 minutes. However, by a wave-length of 5.6 meters they were killed in 20 to 25 seconds. Fungi were inoculated into agar media before treatment. At 45° C., the agar commenced to melt when in the condenser during the treatment, but in a water bath, melting begins only after a temperature of 80° C. has been reached. Lethal effects of the above-mentioned frequencies began when the temperature of the medium registered 30° to 40° C.—temperatures that are not lethal under ordinary conditions.

EFFECT OF OSCILLATING ELECTROSTATIC FIELDS ON PLANTS AND PLANT PARTS

Lakhovsky (105–109), who was the first to study the effect of ultra-short radiation on plant-tumor tissue, noted no ill effects of high-frequency currents on geranium plants. Later workers investigating the effect of high-frequency electrostatic fields on seeds reported under some conditions a definite stimulation of germination. Headlee (76), working with frequencies from 750,000 c.p.s. to 14,778,000 c.p.s., observed no injury to wheat seeds when employing frequencies of 700,000 c.p.s. to 3,000,000 c.p.s., even at 80 minutes' exposure. Seeds exposed

at 5,000,000 c.p.s. for 10 minutes were reduced in germination to 54 per cent at 160° F., as compared with 88.6 per cent germination of the checks. This shows a marked differential between lethality for a host and a pest, since insects are killed sooner.

McKinley (121) exposed seeds of Golden Bantam corn to a frequency current, varying from 5 minutes to an hour. Seeds were killed at these exposures. With a one-minute exposure seeds were not killed but slightly retarded in germination, while "from 30 to 40 seconds, the growth of the seedlings was accelerated in the early germination period."

TABLE 2

Effect of high-frequency electrostatic field (hfe) on germination of carrot and onion seeds (Wave-length 5.7 m.)

SEED	CHECK	2 SEC.	5 SEC.	10 SEC.	15 SEC.
	Per cent germination				
Carrot.....	32	63	42	36	25
Onion.....	30	82	80	69	52

Bean seeds exposed to an oscillating current in a field strength of 3977.6 volts and a frequency of 1,090,000 c.p.s. did not lose their germinating power while this exposure proved lethal to bean weevils, according to Hadjinicolaou (64).

Vishniakova (226) found that at all voltage gradients a longer exposure was required to cause a decrease in germination of seeds than was necessary to kill insects. When seeds are between the plates the temperature of wheat seeds at which a marked decrease in germination was observed lies between 50 and 60° C. Siniuk (205) studied seeds which were aged and low in germination. With an apparatus having a field strength of 3000 volts, 8 amperes in a secondary circuit, with plates 8 cms. in diameter (separated 50 mm.), and tuned to 5.7 meters, he found that 2 seconds exposure increased the germination of onion, carrot, and wheat seeds (Table 2).

Currents of a circuit tuned to 11 meters decreased the germination of wheat seeds about 68 per cent when they were exposed for 1.5 minutes. Less damage occurred at 1 minute and practically no injury from 30 seconds or less, according to Andreiv and Balkashin (3).

Some chemical changes occurring in seed during the treatment between condenser plates of the oscillator were reported by Frolov (51). These changes are: decrease in starch, increase in sugar (probably invert sugar), and changes in albumin. An increase in germination and the energy of germination (energy of germination refers to the percentage of seeds which germinated three days after seeds were placed in a germinator) were noticed. Kuperman (103) investigated the effect of high-frequency currents tuned to 7 to 8 meters with a voltage gradient 1200 $\frac{\text{volt}}{\text{cm}^2}$ on yield, weight, and general growth of cucumbers, tomato, and cotton seed. Cucumbers treated for 10 seconds showed an average increase in yield from 473 grams to 584 grams per plant, as well as an increase in dry weight of the plants. Seeds treated for 20 seconds (volt grad. 1000 $\frac{\text{volt}}{\text{cm}^2}$) and 5 seconds (volt grad. 1200 $\frac{\text{volt}}{\text{cm}^2}$) gave plants which began to bear fruit 9 days earlier than the checks. Tomato seeds exposed for 5 to 10 seconds (volt grad. 1200 $\frac{\text{volt}}{\text{cm}^2}$) began to fruit 11 days earlier than the checks. The number of fruits on tomato plants from treated seed was 118 to 134 per cent as compared with the controls. Cotton seeds treated for 2 to 5 seconds at a

voltage gradient of 316 $\frac{\text{volt}}{\text{cm}^2}$ gave plants that formed flower buds 8 to 10 days earlier than the checks, and buds opened 27 days earlier. The relation of moisture content of seed to heating when seeds are treated was discussed by Sharoiko (203). Interesting data were presented by Pospelov, Zhilenkov, Burnatzky and Buromsky (161) on treating milo seeds contaminated with smut spores and on stimulation of germination in oats, wheat, and milo. Energy of germination was the best in all three cases when seeds were rayed in a field tuned to 7 meters and exposed for 5 seconds. An increase in energy of germination occurred at 5 meters, at 30 seconds exposure. Smut spores on milo seeds treated by a 5 meter wave-length for less than one minute were killed completely, the seeds not being injured in any way. Chemical analyses of wheat seeds treated by a current tuned to 5 meters with an exposure of 30 seconds are shown in Table 3.

These results showed that the percentage of albumin decreases in treated seeds. Increase in peroxidase parallel with an increase in energy of germination and increase in green weight and flowering 5 days earlier than a check was observed by Tarusov (218, 219) for a blue lupin subjected to treatment by high-frequency currents. Increase in peroxidase takes place in dry as well as in moistened seeds and persists long after treatment.

Wheat seeds artificially infected with *Fusarium* sp. gave 97 per cent germination when irradiated by a high-frequency electrostatic current oscillating at a wavelength of 5.6 meters and exposed for one minute; 90 per cent at 2 minutes exposure; 80 per cent at 4 minutes; and 45 per cent at 6 minutes exposure. *Fusarium* sp. died after exposures of 2 minutes and longer. Thus, for example, it may be possible to disinfect wheat seeds for fungus diseases caused by smuts, *Fusarium* and *Helminthosporium* sp., etc., concludes Tverskoi.

High-frequency currents are capable of inducing some changes in the chromosome apparatus of plant cells. Krajevoj (102) reported a fragmentation of chromatin material of the nucleus, translocations, and the phenomenon of "somatic reduction" when pea seeds were exposed to a high-frequency electrostatic field.

High-frequency electrostatic fields may be used to temporarily inactivate and enhance the enzymatic mechanism of fruits and vegetables, and thus may be of service in storage preservation and ripening of those products (26, 27, 28). Results obtained by Cerevitinov and Metlitzky (28) indicate it is possible to prolong keeping time of apples, pears and grapes and to hasten the ripening of green tomatoes. Grapes which were exposed for one minute (8 mg.p.s.) gave, at the end of 23 days of storage, 3.5 times less overripe than those treated 1 second and 10 times less than the controls. There was no decrease in vitamin C content in treated materials. Green tomatoes rayed for one minute ripened 14 days later, while only 62 per cent of the controls ripened (cf. Table 4).

TABLE 3

Albumin content of wheat seeds treated in a high-frequency electrostatic field tuned to 5 meters

	PER CENT OF ALBUMIN
Check (untreated; not germinated)....	14.6
Check (untreated; in germinator 1 day)	12.3
Check (untreated; in germinator 2 days)	11.33
Treated (in germinator 1 day).....	9.56
Treated (in germinator 2 days).....	8.59

What is the mechanism of action in high-frequency fields? No definite answer to this highly important question can be

given at present. Many theories attempt to explain different phenomena induced by high-frequency currents. The principal explanations are: heat produced as a result of energy absorption by the treated material (conduction currents); resonance theory; effect of dipoles, and specific effect. Detailed information on these topics is contained in certain papers (4, 21, 24, 35, 36, 38, 39, 40, 45, 52, 74, 75, 77, 80, 97, 98, 100, 110, 113, 114, 115, 126, 127, 128, 134, 137, 138, 140, 142, 153, 156, 157, 158, 187–190, 191–197, 204, 206, 215, 220).

ECONOMICS OF HIGH-FREQUENCY TREATMENT

Mouromtseff (146) stated that irrespective of the conditions, the safe minimum of energy for 100 per cent kill of weevils was 443 watt-seconds per cubic inch. If we assume 450 watt-seconds of energy per cubic inch then it will give us 970,000 watt-seconds per bushel (450 x 2150) or 0.27 kilowatt-hour per bushel of wheat. If the overall efficiency were 40 per cent, the necessary input will be 0.67 kilowatt-hour per bushel. "From this it can be concluded that the high-frequency treatment of wheat proves to be economically sound," concludes Mouromtseff.

Since 1934, 14 scientific institutions in Russia have been engaged in research on possible utilization of ultra-short radio waves in agriculture, i.e. for cleaning seeds from insect pests, smuts, and increasing yields of various crops. As a result of this intensive work (141,219) 92 hectares of truck crops, oil-yielding plants, etc. were planted in 1935 with rayed seeds. These were orientation tests in order to determine the best dosage for seeds under different conditions. In 1936, sufficient seeds were rayed to plant: 7232 hectares of cotton, 4000 hectares of corn, 1100 hectares of castor bean, and 100 hectares of vegetables. The results were as follows: —Cotton, an increase in yield from 0.3 to 4 centners per hectare (1 hectare equals 2.5 acres; 1 centner equals 220 pounds); castor bean, an average increase of 1.05 centners per hectare, or about 17 per cent.

TABLE 4

Effect of high-frequency oscillating fields on tomatoes (after Cervitinov and Metlitzki (28))

NO.	DURATION OF IRRADIATION	CONDITION OF TOMATOES AFTER 14 DAYS OF STORAGE					
		Flesh colored	Brown	Pink	Red	Culls	Damaged
1	1 second	12.5	25	12.5	50	—	12.5
2	5 seconds	25	25	—	50	—	12.5
3	30 seconds	25	12.5	37.5	25	25	12.5
4	1 minute	—	—	12.5	87.5	12.5	—
5	3 minutes	12.5	37.5	12.5	37.5	12.5	—
6	check	12.5	25	12.5	50	12.5	25

On some farms employing superior methods, the increase amounted to 3 centners per hectare. The yield of vegetables increased from 70 to 80 per cent. The potato yield increased 100 per cent, and the sunflower crop from 50 to 60 per cent (controls, 15.4 $\frac{\text{centr.}}{\text{hect.}}$; treated, 23 $\frac{\text{centr.}}{\text{hect.}}$ or an increase of 7 $\frac{\text{centr.}}{\text{hect.}}$).

In 1937, Dnepropetrovsk province planned to treat seed enough to plant 240,000 hectares, or 600,000 acres, as follows: cotton, 60,000 hectares; corn, 119 hectares; castor bean, 15,800 hectares; vegetables, 11,315 hectares; watermelons, cantaloupes, etc., 29,310 hectares; pota-

toes, 2950 hectares. At present, Dnepropetrovsk province has about 10 high-frequency treaters (treating stations) using oscillators consisting of 2 tubes of 400 watts, tuned to 7 to 8 meters. The generator capacity is 15 tons per working day of 10 hours, with an average of 3000 pounds per hour.

DISCUSSION

High-frequency electrostatic fields cause some definite changes in biological material. Although the real mechanism by which changes occur in various materials exposed to the action of oscillating electrostatic fields has not been established with certainty, the application of the phenomenon to various problems in biology and in particular to some branches of agricultural science should not be overlooked. Numerous investigations show that insect pests, fungi, and bacteria may be destroyed by heat induced by the passage of electric forces (3, 43, 44, 60, 64, 75, 84, 161, 223, 224, 226). It may be that only certain vital parts of the living object are heated momentarily to such a degree that death ensues. This is in accord with Malov's theory of "point heat" (134, 137, 138).

Inasmuch as it is both interesting and important to know the underlying causes of the effects of high-frequency electrostatic fields, the value of it is readily grasped when the destructive work of various cereal weevils can be controlled permanently by a simple, inexpensive and non-chemical procedure (34, 146) or when wood-destroying fungi may be destroyed by passing lumber between the plates of oscillating generator (84) thus saving considerably in terms of labor and expense.

These experiments indicate that seed-borne pathogens (bacteria and fungi) may be destroyed on or in the seeds without injuring the latter. It may also be possible to increase the power of germination of seeds whose germination has been lowered appreciably or which are naturally more difficult to germinate.

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SEX DIFFERENCES IN MORBIDITY AND MORTALITY (*Concluded*)

By ANTONIO CIOCCO

Department of Biology, School of Hygiene and Public Health, The Johns Hopkins University

Age and the differences in mortality between the sexes

ONE of the main differences between the males and females, particularly in relation to the circulatory system, has been the higher mortality of the males from these causes that are characteristically associated with advancing age. The mortality rates for the five gross divisions of the age range used in Table 7, bear this out and also bring out a number of additional facts about the behavior of the two sexes with regard to mortality.

Considering the deaths from all categories and for all the age groups, it is seen that the absolute differences between the rates of the males and of the females is greatest for the deaths under 1 year of age, reaches a minimum for the 5 to 14 age group and increases thereafter. There are thus two age periods: infancy and late adulthood and old age in which the males exhibit a markedly higher mortality than the females. The higher male mortality during infancy in part is due to what might be regarded as the extension into postnatal life of the factors responsible for the high masculinity of stillbirths. Thus one notes the great difference between male and female infants relative to the mortality from prematurity and from injury at birth; both conditions discussed already in the previous section. Among the other causes that cannot be allocated to any particular organ system those classed as violent and accidental deaths deserve some attention. At all ages, the mortality of the males from these causes is higher than that of the females. For the ages above 5 this might be explained by the differences in the environment of the two sexes, occupation for example, or merely the different exposure to risk due to the greater activity of the boy and man. Except that probably the male is more active than the female, it is difficult to imagine a greater exposure to risk of death for the male infant and yet the data show that for the ages under 5 the mortality rates from causes listed under these categories is higher in the males. For example, it is higher in the case of deaths from mechanical suffocation, drowning and falls and yet for all of these it would seem that the element of chance is alone involved. If it could be definitely shown that in the two youngest age groups as many or more females than males are subject to such accidents, the argument of those who believe in the inherent inferiority of the male would be greatly strengthened. At present a categorical position in the affirmative or negative cannot be taken although unpublished data, use of which has been kindly permitted by Dr. S. D. Collins of the United States Public Health Service, would seem to indicate that in infancy the incidence rate of accidents is actually higher in the

males than females. In a periodical canvass of 9,000 families made under Dr. Collins' direction from 1928–1931 (cf. Collins, 1940), twenty-eight accidents of all types were recorded for male infants and sixteen for female. The rates per 1,000 person-years experience as computed by Collins are, 41.6 for males and 32.7 for females. The male's superiority in incidence rate is then of the same order as that noted with respect to mortality. In this communication, however, Collins remarks that the difference between the male and female rates equals 8.9 ± 8.2 and is therefore statistically insignificant. Increased information is obviously needed.

When the sex differences in mortality due to the break-down of the several organ systems are considered in relation to age, the pattern of these differences becomes more definite if none the less complex. For deaths due to a break-down of the circulatory system, the higher male mortality is noticeable at the two extremes of the age range. In infancy the higher male mortality is due almost entirely to congenital malformations of the heart, already mentioned. As has also been already stated there is a higher male mortality from diseases of the chronic degenerative type and the effects of this are to be noted for the 50 years and over group.

TABLE 7

Mortality rates of males and females according to organ system involved. White population of the United States Registration Area, 1930

ORGAN-SYSTEM	MORTALITY RATES									
	Per 100,000 births		Per 100,000 population							
	Age classes (*in years*)									
	Under 1		1 to 4		5 to 14		15 to 49		50 and over	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
Circulatory, blood	439.8	317.8	32.0	28.3	20.5	20.6	66.7	52.5	1238.4	1037.8
Respiratory	1273.2	1075.4	199.0	183.5	33.7	33.3	118.0	92.2	423.0	344.7
Primary and secondary sex organs	56.2	42.3	1.4	1.2	.3	.8	6.5	75.4	124.0	197.1
Kidney and related excretory organs	23.4	23.6	7.1	7.1	4.1	4.9	25.7	33.4	466.2	395.3
Skeletal and muscular system	21.6	17.5	5.2	4.8	5.9	5.0	4.9	3.9	18.0	20.5
Alimentary tract and associated organs	1010.9	784.0	145.3	115.7	29.7	26.1	67.7	56.8	483.6	412.7
Nervous system and sense organs	245.2	237.6	49.3	42.8	23.7	17.0	66.8	36.7	578.3	499.9
Skin	56.0	51.7	2.2	2.9	.9	.8	2.8	2.3	27.9	19.8
Endocrinal system	78.5	54.1	4.2	3.7	2.2	2.7	5.9	10.7	72.8	136.1
Non-specific causes of death										
Violent and accidental deaths	101.4	84.2	66.8	51.2	49.2	20.8	117.5	23.2	218.5	136.1
Premature births	1777.8	1458.2	—	—	—	—	—	—	—	—
Injury at birth	595.9	399.5	—	—	—	—	—	—	—	—
Others	921.3	659.7	14.2	13.3	3.4	2.8	8.2	7.1	99.5	99.2
All deaths	6601.2	5205.6	526.7	454.5	173.5	134.8	490.7	394.2	3750.2	3309.2

A notable exception to the higher masculine mortality from cardiovascular diseases is constituted by diseases of the endocardium for which neither sex prevails consistently and from 5 to 49 years of age the females have the higher mortality. For the under 1 age group the male death rate (per 100,000) is 13.7 compared to 10.8 for the females, in the next age group it is respectively 3.3 and 3.0, for the 5 to 14 years age groups instead one finds 7.6 males and 8.9 females, and for the 15 to 49 years age period the rates are respectively 19.7 and 20.5. After 50 years of age there is again a return to a higher male mortality, the rate being 243.2 as compared to 231.2 in the females.

Altogether, the sex differences among deaths from causes demonstrating a break-down of the respiratory system follow the same age pattern as those from diseases of the circulatory system. The highest differences occur at the two extreme age groups. There are, however, some notable exceptions to the general higher death rate of the males from this group of causes. In the first place, at all ages more females than males die of whooping cough. Secondly, at the oldest ages more women than men die from bronchitis (all forms) and from influenza (all forms). For the former condition the mortality of the males equals 84.8 compared to 90.9 for the females, for the latter the rates are, respectively, 47.1 and 50.9. Thus, the data suggest that the higher male mortality from respiratory conditions is a consequence mainly of a greater liability to a break-down of the lungs proper. For the time being, the comparative female mortality from whooping cough and, in the older ages, from bronchial diseases cannot be attributed to a weakness of any specific organ or structure although it is to be noted that in the complex pathological picture of whooping cough deaths are found those lesions of the bronchi and lungs to which MacCallum has given the name of interstitial bronchial pneumonia.

As it is apparent in Table 7, the differences in the mortality between the males and females from conditions involving the nervous system do not become striking until the adult years are reached. This is to be expected since among the death causes that exhibit a high masculinity are alcoholism, suicide, tabes dorsalis, and general paresis. In infancy and childhood the prevalence of meningitis among the males is offset by the higher female mortality rates from congenital hydrocephalus and spina bifida meningoceli. It will be recalled that both of these conditions, when they cause stillbirths, are also found more often in females. Incidentally, the most important cause of death in the oldest age group, cerebral hemorrhage, affects the females slightly more than the males in that period. In the younger age classes it is relatively prevalent at times in the males and at others in females.

A study of the age specific rates for the diseases listed under alimentary tract does not alter sensibly the picture presented above. The higher rate for the male infants relative to diseases of the alimentary tract results from the high masulinity of deaths due to diarrhea and enteritis. The preponderance of the males then, seems to be associated particularly with a break-down of what might be considered the gastro-intestinal tube while, in general, the females seem to show greater liability to a functional failure of the specialized glands which represent a later development of the embryonic gut. The apparent exception is cirrhosis of the liver, but the greater masculine mortality from this condition may actually be the result of environmental factors.

In passing, it will be observed that other diseases of the pancreas besides diabetes and other diseases of the gall bladder besides biliary calculi show a higher female mortality. This has important significance inasmuch as it suggests that the tendency of the gall bladder and pancreas to break-down more often in the case of the female does not depend upon a particular etiological factor.

As the data of both Tables 5 and 7 indicate, the higher mortality of the males due to the break-down of kidneys and related excretory organs is concentrated entirely in the age class of 50 years and above. In the three youngest groups there is very little difference between the rate of the males and females, and for the 15 to 49 years age class the women definitely have higher rates, as expected from the incidence of puerperal albuminuria and eclampsia.

For the causes of death listed in the skeletal and muscular system there is a consistent though not marked higher masculinity until the age class 50 and over is reached. In this group there is a prevalence of women. The preponderance of males noted in the first four age groups is associated principally with rickets, osteomyelitis, tuberculosis of the bones, joints and vertebrae. The females instead show a higher relative frequency in relation to acute rheumatic fever and chronic rheumatism. Although the number of cases on which these rates are based is not large, corroborative evidence will be presented later to show that these findings probably present a true picture of the sex differences in the mortality from these conditions.

The age trend of the comparative mortality rates from causes included in the group of endocrine diseases and in that of the primary and secondary sex organs exhibits a noteworthy parallelism. Relative to both groups the males have a higher rate in the first year of life. This is associated with diseases of the thymus and with congenital syphilis. The higher male mortality during infancy from congenital syphilis is in accordance with the findings on stillbirths and the question is again raised whether the sex selectivity is dependent upon the inferior resistance of the male or to a previous elimination of the females in the early stages of embryonic life. The higher female rates found after adolescence for deaths due to the break-down of the endocrinal system and that of the primary and secondary sex organs are associated with diabetes, diseases of the thyroid and with diseases related to pregnancy. The latter furnish the bulk of the female mortality from diseases included in the class of primary and secondary sex organs, but it is of importance to note that during adulthood cancer and other tumors of the breast contribute heavily to the female mortality. From this sketchy statistical description of the sex differences in the post-natal mortality for the year 1930 among the white persons in this country, a number of important deductions can be drawn. It appears, first of all, that during childhood and adolescence the sex differences in mortality—the higher mortality of the males—is barely perceptible. The trend of the differences, if considered by itself, would suggest that two series of factors are responsible for the higher male mortality. One factor would be the inherent biological inferiority of the males that brings about the elimination of the weaker in the early period of life. The other would be the environmental conditions related to the particular functions of the male in the social group. Secondly, considering the mortality due to the break-down of the several principal organ-systems, it is seen that not for all groups of

diseases do the males exhibit a higher mortality, and in those instances where they do have a higher death rate, it is in general due to only some of the diseases included in the category. Furthermore, when the causes of death for which the males definitely predominate are examined, one notes: pneumonia, cancer of the skin, alcoholism, suicide, diarrhea and enteritis, tabes dorsalis, general paresis, stomach and duodenal ulcers, all conditions in which the environment and the social function of the male may play a very important part. On the other hand, the males have a markedly higher mortality from diseases involving the arteries and the myocardial layer of the heart and from malignancies of the buccal cavity, digestive tract, and bladder. So far as any precise knowledge of the etiology of these conditions is available, it would seem that they are probably dependent more upon the inherent biological constitution than on other factors. There are certain causes of death for which there is not a male but a female preponderance. It is particularly noticeable that the females die more than the males from the diseases of the gall bladder and of the thyroid. The more frequent break-down of the endocrinal system in the females is not only found relative to the thyroid but also in relation to the pancreas; the diabetic mortality being much higher in this sex.

From the detailed consideration of the causes responsible for the deaths, it is seen that the so-called inferiority of the male is not general but specific, that is, it is limited to certain conditions. In turn, the females also manifest a greater liability to particular causes of death. In addition, however, it becomes clear that for those diseases or groups for which either of the two sexes demonstrate a higher mortality the causal element may not be always connected with maleness or femaleness. The higher male mortality during infancy might be considered as an indication of an inferior biological structure. However, even in this case, caution must be used in assuming that exposure to risk of dying is equal in the two sexes. Bearing on this point are the data reported with reference to accident incidence. *A priori*, it would seem that among infants the liability to accidents should be equal in the two sexes, but apparently it may not be so. Therefore, it is of great importance to ascertain, so far as the available information permits, whether the differences in mortality noted above result from a difference in liability to a particular cause of death or in resistance to it.

Morbidity in the two sexes

With but few exceptions adequate data regarding the attack or case rate of illnesses do not exist. For the majority of diseases the only information available is that given in the summaries of clinical and hospital reports, which in general express the sex differences in terms of ratios of males to females, or else just mention whether there is a preponderance of one or the other sex in the sample collected. Such statistics are faulty for a number of obvious reasons. The method of selection of the sample, the age distribution, the race (color) and other characteristics of the individuals are omitted more often than not. Furthermore the size of the sample is rarely large enough since usually it represents the experience of one man or one clinic. In order to obviate some of the inadequacies of the available information an attempt has been made to bring together here the conclusions reached by a number of observers and authorities. But while the medical literature on the subject has been investigated as thoroughly as possible, for the purpose of this paper only those reports have been utilized

that deal with the disease conditions noted above and for which the mortality rate of one sex is significantly higher than that of the other. So far as was feasible only data based on the white population of this country have been used.

In the same order as above the diseases are presented, grouped in the 9 categories of Pearl's classification.

I. *Circulatory system, blood and blood-forming organs.* Arteriosclerosis is found more often in males according to all students of the subject (cf. Boyd, 1938). Evidence to support such an assertion is plentiful. In the morbidity survey made by De Porte (1933) in rural New York State it was found that of 1934 individuals 9.9 percent of the males and 7.7 percent of the females had arteriosclerosis. Wykoff and Lingg (1926) report that the males constituted 75 percent of the 234 persons with arteriosclerosis they encountered in the survey they conducted for the New York Heart Association. The experience of the Mayo Clinic, according to Allen (1934), demonstrates that over 5 times more males than females are affected by this condition. In addition to arteriosclerosis, thrombo-angiitis obliterans, a disease of the arterioles, also occurs with greater frequency among the males according to Allen's report, the ratio being 90 males to 1 female. As a matter of fact it is probably higher since as Boyd says it is a condition practically confined to the male sex alone. Allen and also Goodridge (1929) cite Buerger as having seen only 3 women in 500 cases.

Among the other diseases in this class one notes as for the mortality, a prevalence of males among the persons affected by diseases of the myocardium, the coronary vessels, the aorta and pericardium; and the several clinical surveys and observations are all in agreement. For example, Sprague (1937) concludes that coronary sclerosis occurs three times as often in males as in females. Such is the opinion of White (1937) relative to coronary insufficiency, although for this condition the ratios reported reach 30 to 1. Myocardial degeneration has been seen twice as frequently in males as in females according to Eggleston (1929). Allen (1934) reports a ratio of 7 to 1 for myocardial infarction. Angina pectoris is well known to occur from four to six times more often in males [cf. Allen (1934), Brooks (1929), Boyd (1938), Smith (1934), etc.]; so also does aneurysm of the aorta, syphilitic heart disease and aortitis, according to Cowan and Ritchie (1935), Osler (1935), Smith (1934), Brown (1929), Christian (1935), and De Porte (1933). Pericarditis is also found to be more frequent in males [cf. Osler (1935), Morris (1929), Smith (1934)], the ratio being about two to one according to Allen's experience.

The age variations in the sex incidence of morbidity from endocarditis apparently parallel in certain respects that observed in mortality. Chronic mitral endocarditis is apparently more frequently in females according to Allen, the ratio being about two to one. White believes that in general women are more prone to valvular heart disease because they are more liable to rheumatic infection which is by far the most important etiological factor associated with this form of heart disease, particularly in childhood and youth. However, with advancing age arteriosclerosis and syphilis accompany this disease more often and since they are preponderant in men, the sex ratio is altered. It is the etiologic factor then and not a specific sex weakness of the structure that brings about the alternative greater female and male mortality from valvular heart disease. In effect, the conditions which

constitute what is diagnosed as rheumatic heart disease prevail in females by two to one in Coombs's (1924) series of cases, although in De Porte's and Wykoff and Lingg's data the ratio was somewhat lower. Wilson *et al.* (1928), however, from their observations on children obtained the same results as did Coombs.

Summing up, it is found that there is correspondence between the sex incidence in morbidity and in mortality from the more important diseases associated with a break-down of the heart and circulatory system.

II. *Respiratory system.* In this group lobar pneumonia and pleurisy are the causes of death that manifest a significantly high masculinity and it would seem that these diseases actually occur more often in the males. In Osler's textbook it is stated that in 12,098 collected cases of lobar pneumonia, 73 percent were males and 27 percent females. Hoffman's (1913) summary of the Johns Hopkins Hospital experience from 1892 to 1911 shows that 341 male white patients and only 102 white females were admitted for diseases of the lungs (tuberculosis not included) during that period. During 15 years of observation at that hospital, according to Osler, 194 patients with serofibrinous pleurisy were seen and of these 161 were males and 33 females. On the whole this illustrates the general observations reported by Barach (1933), Trask (1937), Cecil (1937), Austrian (1939), Stallybrass (1931) and others. De Porte's 1927 morbidity survey in rural New York State showed that acute lobar pneumonia was reported in 78 males and 53 females.

What data there are on the sex frequency of influenza in non-epidemic conditions are not useful for the purposes of this study due to a variety of reasons. In the 1918 epidemic, Frost's (1919) study indicates that on the whole the attack rates were higher for the females than for the males. Vaughan's (1921) observations of the 1920 epidemic in Boston bring out a similar relation. In addition, Vaughan says that, on the average, the women had also a higher proportion of severe cases. A very interesting observation is reported by Frost regarding the case fatality from influenza during the 1918 epidemic. He noted that between the ages of 15 and 60 the men, not the women, had a higher fatality rate. This is accounted for by a higher incidence of pneumonia in the males together with a higher mortality from this disease. Vaughan, in the epidemic he studied, found the same—5.2 percent of the males developed pneumonia and recovered and 1.9 per cent died, while 3.6 per cent of the females developed non-fatal and .4 per cent developed fatal pneumonia. Although it may be that epidemic influenza has characteristics of its own, these findings would suggest that the higher masculine mortality from this disease at several age periods may be due entirely to the greater susceptibility of the male to pneumonia.

Whooping cough is one of the major causes of death showing at all ages a female instead of a male preponderance. Data on the attack rate of the disease in general appear to reveal the same. Godfrey's (1928) observations in New York State inclusive of New York City, Laing and Hay's report from Aberdeen (1901), the report of the British Medical Research Council (1938), all note that the females are attacked relatively more often than the males. Sydenstricker's (1928) data from Hagerstown, Maryland, and De Porte's findings in rural New York are the only two studies where a slight excess of males has been found among the cases having the disease. Since the frequency of deaths from this disease is somewhat

unusual relative to the sex incidence many have speculated upon its significance. Holmes (1926), Young and Russell (1927, and Hill (1933) have all discussed the matter at length. They have come to the conclusion that the sex differences are not associated with differences in size of larynx or with peculiar sensitivity of the nervous system but rather to a difference in susceptibility to the specific organism.

IV. *Kidneys and related excretory organs.* As the data on mortality have shown, on the whole for this group of conditions there is not a striking difference between males and females. In Osler's textbook it is stated that the males are rather more subject to chronic nephritis than are the women. Hoffman's study of the admissions at the Johns Hopkins reveals that 575 males and 521 females were found to have diseases of the kidneys. However, Allen's report from the Mayo Clinic would indicate that twice as many males as females are affected with glomerular nephritis. On the other hand, De Porte reports that more females than males were found to have chronic interstitial nephritis (Bright's disease) in the morbidity survey in rural New York, the figures being 652 women and 482 men. A similar relation was observed for acute nephritis: 285 females and only 165 males being reported. In a way, these last findings would seem to contrast with McCann's (1934) statement that acute hemorrhagic nephritis is found with about equal frequency in both sexes during childhood but that later in life the males have a higher incidence. Altogether these observations suggest, then, that there is no clear-cut predominance of one or the other sex with respect to diseases causing directly the break-down of the kidneys.

V. *Skeletal and muscular system.* On the whole, the sex incidence of the diseases of this group corresponds to that observed relative to mortality. Osteomyelitis, as Allen shows, is found twice more often among males than among females. With regard to rickets, there is some uncertainty about a sex difference in susceptibility. Hess (1929) is unable to arrive at any definitive conclusion although he and others have observed late rachitic sequelae more often in boys than in girls.

Taking together all manifestations of rheumatic fever, the consensus of opinion is that it occurs more often in females than males during the age period of its highest incidence, childhood and adolescence. Osler (1935), Swift (1937), Torrey (1935), and Sydenstricker (1934) concur in this conclusion. Thomson and Findlay's (1933) report on 701 children seen in Glasgow supports this view. Of these, 63 per cent were girls and 37 per cent were boys. While at later ages there appears to be no sex difference in the attack rate, or maybe a slight masculine predominance, the higher fatality noted for the females can be accounted for by the association of the childhood disease to endocarditis.

Chronic arthritis also occurs more often in females, if gout is excepted. Glover (1928), who has summarized his own and other data on the subject, notes that for this disease the females are twice as susceptible as the males. This is in fair agreement with the observations of Torrey (1934), those of Cecil (1937), Allen (1934) and others. In De Porte's survey, 1092 males as compared to 1148 females were affected by this condition. It should be noted here that Dawson believes that the female prevalence is to be observed particularly during the period of sexual maturation and at the menopause.

VI. *Alimentary tract and associated organs concerned in metabolism.* The higher mortality of the males from diseases of the intestinal tract is apparently associated

with a higher male morbidity from such conditions. Boyd (1938), Griffith and Graeme Mitchell (1937), Hempelmann (1935), and others have noted that malformations and abnormalities of this organ system are found more often in males. For example in 358 cases of Meckel's diverticulum that Boyd collected, only 72 were in girls.

Duodenal ulcers occur much more frequently in males than females. Eusterman and Balfour (1936) for instance have operated on 551 males and only 150 females. Hosoi and Alverez (1930) found a ratio of over three males to one female in the series collected at the Mayo Clinic. An interesting observation by these authors is that gastrojejunal ulcer has been found over seven times more often in males but simple gastric ulcer is observed somewhat more frequently in females. In Osler's textbook a statement to the same effect is made and Brown (1929) cites the results of Moynihan's clinic where in 164 operations for simple gastric ulcers, 83 were on men and 81 on women. These findings indicate then that males tend statistically to show an organ weakness relative to the intestinal tract, but not to so marked a degree for the stomach. This is in agreement with the mortality data reported above where the sex differences were significant only with respect to the intestinal tract, while for the deaths from diseases of the stomach the proportion of the sexes was not strikingly different. Further confirmation on this point is obtained from the report of Hosoi and Alvarez. These authors have observed more males than females among cases of cancer of the intestines, but about an equal number of men and women among cases of cancer of the stomach. Cirrhosis of the liver and malignancy of this organ are somewhat more frequent in males than females. But Hosoi and Alvarez's data indicate that this masculine preponderance is not very marked, since in their series the ratio was about 1.3 to 1. Other writers, as for example Stengel and Kerr (1922) and Rolleston and McNee (1929), raise this ratio to between 2 and 3 to 1.

While acute appendicitis, according to Lewis (1929), is more common in men, since he found 959 males (60 per cent) in a series of 1577 cases, Hosoi and Alvarez find only a slightly higher number of males in the series of cases they record. De Porte reports 453 men and 513 women among the cases of appendicitis noted in the morbidity survey of 1927 in rural New York. It would seem then that the sex differences in the mortality from this condition are not associated always with a corresponding difference in morbidity. It must be remembered, however, that the fatality rate from this condition depends on a number of extraneous circumstances not connected with the individual physical resistance. The same can be said about typhoid fever for which the mortality was found higher in the males. The attack rate for this disease depends entirely on the cause of the outbreak. Whether or not males are more apt to die, everything being equal, is a matter regarding which there is little conclusive evidence.

Pellagra is one of the conditions in this class for which the mortality is higher in the females. Goldberger *et al.* (1929), Vanderhoff (1929), Zimmerman (1937), Musser (1934) all agree that women are slightly more susceptible. Official statistics (1926) regarding admissions to institutions for mentally deranged reveal that in 1922 the first admission rate from pellagra psychosis was for white urban males equal to 0.1 per 100,000 population, for the females it was 0.3. For males coming from rural areas the rate was 0.3 while for females it was 0.8.

A break-down of the gall bladder also causes death in more females than males. Boyd (1938) says that females are always more subject to it. Hosoi and Alvarez noted cholelithiasis almost three times as frequent, and cancer of the gall bladder almost four times more often in women than men. For the latter disease, Rolleston and McNee (1929) have summarized the findings reported in the literature, both American and foreign, and state that the rate of females to males varies from 3 to 1, to 5 to 1. These same authors report that in general gall-stones are said to occur from two to three times more often in women than in men, a statement with which there appears to be general agreement.

VII. *Nervous system and sense organs.* There is no doubt that tabes dorsalis not only causes more deaths among males than females but is also found more often among men. Osler and also Stallybrass have stated that 10 males to 1 female are affected by this condition. As a matter of fact all forms of neurosyphilis occur more often in men according to the above authors and others. The question, however, is whether or not this male preponderance is not dependent upon the higher rate of syphilis among men, a fact well established [cf. Le Blanc (1925)]. Turner's (1930) data based on 10,000 consecutive hospital admissions would indicate that the higher incidence of syphilis among men is not in itself responsible for the frequency with which central nervous system involvement occurs in this sex but that actually the males seem to be more prone to neurosyphilis. He found that 39 per cent of the male syphilitics had some form of neurosyphilis as compared to only 22 per cent of the females.

Among the diseases included in this group the various forms of meningitis all show a masculine preponderance in attack as well as mortality rate. Levinson (1937) is of the opinion that all forms of meningitis, independently of the etiologic factors, occur more often in males. Meningococcic meningitis he thinks is found 1½ times more often in males than in females. Purulent and tuberculosis meningitis also occur in the two sexes in the above proportion. Kempf *et al.* (1933) in the Indianapolis epidemic of meningococcic meningitis found even a higher ratio, 80 per cent of their cases being males.

This apparent liability of the meninges of the males to various forms of disease is also shown by Hoffman's (1913) report. He grouped together diseases of the brain, spinal cord and meninges and in this series are included 360 males and only 140 females. Diseases of the cranial and spinal nerves were found instead in 143 males and 142 females.

Dementia praecox is the one disease in this group for which the mortality in the females is somewhat higher than in the males. But it appears that the attack rate as measured by the first admission rate, shows the reverse. Official statistics for the whole country, as well as Malzberg's (1936) report for New York State, indicate that for this condition the first admission rate to institutions is higher in males. During 1922 in the United States, the number per 100,000 population of males and females admitted with a diagnosis of dementia praecox to institutions equalled 20.3 and 15.8, respectively. This refers to white urban population only. In the white rural population the rates were 9.7 for the males and 7.4 for the females. The mortality of the persons with this condition was, however, higher in the females. During that year the deaths per 1000 under treatment equalled 27.8 for the males and 33.8 for the females.

Thus it would seem that while males are more susceptible to dementia praecox, the course of this disease is more often fatal in females.

VIII. *Skin.* The two diseases in this group showing a definite sex difference in mortality are cancer of the skin and erysipelas. That these have also a higher attack rate in the males is universally accepted, but with fairly good foundation the masculine preponderance is attributed to the influence of differences in environmental exposure.

IX. *Endocrinal system.* Deaths from the break-down of this system occur more often in females because of the frequency of deaths from diabetes and diseases of the thyroid in this sex. That the incidence of the various forms of pathologic involvement of this gland is higher in females has been accepted for some time and the findings reported substantiate the conclusions. Hoffman's data give the number of females with diseases of this gland as 368 compared to only 96 males. Ehrström (1921) and also Means (1934) note that from 2 to 8 times more females than males are affected by endemic goiter. Oleson's (1924) survey of school children in Cincinnati revealed practically the same. Studies and summaries by Bram (1936, Bell (1938, Marine (1937), Osler (1935), DuBois (1929), Kennedy (1937) and Ehrström indicate that the ratio of females to males among those affected by exophthalmic goitre, simple, and colloid goitre ranges between 3 and 10 to 1. A ratio of the same magnitude is reported by DuBois, Marine, and Ehrström in relation to myxoedema.

Diabetes is another disease for which the female mortality is higher. This, according to some students [cf. Drolet (1933)] is really a recent phenomenon and to it there corresponds an increase in the number of cases treated. Joslin (1935) notes that until 1922 his patients comprised 55 per cent males, while after that date only 45 per cent of them were males. In De Porte's survey in 1927 a similar female preponderance was found; of 505 cases with diabetes reported, 332 were in women.

This examination of the reported incidence of certain diseases in the two sexes indicates that, on the whole, the sex frequency with which certain diseases are encountered in clinical practice corresponds to the sex differences in mortality. It is to be understood that these data refer to incidences of conditions so severe as to force the persons to have recourse either to a physician or a clinic. The significance of the findings would be then that on the whole there is none or little difference between the sexes in relation to the fatality from certain diseases once the disease process has reached a severe or moderately severe stage. However, what is desired to know is whether given an equal opportunity to acquire the disease the two sexes differ in their resistance to the pathological action. The relatively meager data bearing on this point are very suggestive. Sydenstricker (1928) in his report on the morbidity survey of the people of Hagerstown, from 1921 to 1924 brought out the important fact that taking all causes and all ages together the annual illness rate was 30 per cent higher in females than in males. Considering the separate groups of diseases he found that the females demonstrated a higher sickness rate from general diseases and from diseases of the respiratory tract, nervous system, eyes and ears, circulatory system and kidneys, digestive system, non-venereal reproductive, and, of course, from puerperal conditions. The males, instead, had higher rates from epidemic, endemic and infectious diseases, diseases of the skin, and accidents. Taking age in-

to account the higher female morbidity rate was observed only after the age of ten while below that age the sickness rates were higher in the males. Furthermore, in children and adolescents Sydenstricker's data indicate that in the age periods when the males have a higher morbidity rate, it is due to existence of a larger moiety of boys who are frequently ill while in the later years, higher morbidity of the females is due both to a greater number of sick persons as well as to a larger moiety of females who are sickly or frequently ill.

Findings similar to these result from the morbidity survey of 9000 families discussed in the very recent report by Collins (1940). The population canvassed is constituted of families in 18 states kept under observation for a period of 12 consecutive months. Collins's data show that on the whole when all causes of sickness are considered the females have sickness rate (cases per 1000) almost 30 per cent higher than the males and although the exclusion of causes associated with genital and puerperal diseases reduced this excess, the female rates were still almost 20 percent higher than the males. The difference between the sexes is particularly noticeable during the adult period and in fact is not of much consequence during childhood. In terms of the diseases for which the sex differences are in evidence the females have a particularly high excess from respiratory, nervous, degenerative, and digestive diseases and rheumatism and related diseases. There is very little difference between the sexes relative to ear and mastoid diseases and skin diseases. On the other hand, the males have a definitely higher sickness rate from accidental causes.

These two sets of observations made at different periods and on different groups deserve particular attention. They indicate that with the exception of accidents the females have after childhood as much or more sickness than the males. Since the information concerning incidence of the single disease entities in the persons surveyed is not given in sufficient detail to permit comparison with the clinical morbidity and mortality experience described above it cannot be determined whether the illnesses acquired by these persons during the period of observation are the same as those that cause death. If it is assumed that the factors involved in the sickness surveyed might also have brought about the fatal break-down of a particular organ then there would be some basis to conclude that the higher mortality of one or the other sex from the causes noted above is due to inferior resistance or recuperative power.

SUMMARY AND DISCUSSION

On the basis of official vital statistics and clinical reports some of the characteristics of the differences in the mortality and morbidity between men and women have been examined. As is well known, the males have a higher mortality throughout practically the whole life span including foetal life, or at least the latter part of it, as well. Demographers and biologists have always been aware of this phenomenon and among the hypotheses advanced to explain it the social and the narrow constitutional viewpoints represent the two extremes.

Considering the whole life span of man, it appears that the difference between the mortality of the males and of the females is greatest in early infancy, including the foetal period probably, decreases to a minimum during childhood and adolescence and increases thereafter. This trend suggests that the higher male mortality in utero and infancy results from the selective process of death which removes the weaker individuals among whom the

males predominate. After this elimination, during childhood, the mortality of the two sexes become about equal. Subsequently, the social function of the male which is accompanied by greater exposure to risks of various sorts might at least partly account for the sex differences in later years. This may well be the basic pattern underlying the phenomenon under discussion but an inquiry into the causes that lead to death reveals that either insufficient knowledge of the factors which contribute to mortality greatly obscure this fundamental pattern, or else that it does not constitute a real explanation of the sex differences. From the analysis of the relative frequency with which the males and females succumb to certain disease entities emerges a fact of the utmost importance to a clear understanding of this phenomenon. It is shown that while for some fatal diseases the males have a higher mortality, for others the females prevail, and for still others there is no appreciable differences between the death rates of the two sexes. During the foetal period males predominate with regard to deaths due to prematurity, diseases of placenta and membranes, asphyxia, prolapse and compression of cord, malpresentation and difficult labor. After birth, they have a higher mortality from angina pectoris, diseases of the coronary arteries, arteriosclerosis, myocarditis, lobar pneumonia, pleurisy, respiratory tuberculosis, rickets, osteomyelitis, tuberculosis of bones and joints, diarrhea and enteritis, duodenal and stomach ulcer, cirrhosis of the liver, appendicitis, cancer of the buccal cavity, digestive tract and skin, tabes dorsalis, general paresis, meningitis (all forms), alcoholism, suicide and accidents. Females have a higher foetal mortality from malformations and a higher post-natal death rate from whooping cough, acute rheumatic fever, chronic rheumatism, pellagra, biliary calculus, diabetes, other diseases of the gall-bladder and pancreas besides these mentioned, and exophthalmic and simple goitre. For the diseases listed here, the greater mortality of one or the other sex occurs throughout the whole life span or throughout the age period when they, the diseases, occur primarily. The age pattern in sex differences might therefore be explained entirely on the basis of the age prevalence of the particular disease for which a sex difference exists. In the light of these findings it must be concluded that neither of the sexes demonstrates a general superior vitality but that each possesses a greater liability to specific and separate fatal conditions.

When the available data on the morbidity of the two sexes are examined it is found that hospital and clinical statistics indicate that the prevalence of the above diseases, respectively, in the males and females corresponds to the relative incidence of the mortality. On the other hand, from surveys made of the general population it appears that on the whole and with the exception of accidents a higher sickness rate is found in the females. One is led then to the conclusion that in general morbific processes, mild and grave, attack the females with greater intensity than the males.

It is not, however, definitely known whether the grave morbific processes—those that bring about the fatal breakdown of an organ-system—occur actually more frequently in the females than in the males. If they do, then the higher female mortality from the conditions specified is an expression of an increased exposure to risk, while the higher male mortality from the other conditions noted indicate an inferior degree of resistance. In this case it would be concluded that the females show a higher recuperative power. If,

instead, for the severe conditions the incidence in the males and females corresponds to that of mortality there is no basis to declare that one or the other sex has inferior resistance but the differences in mortality must be attributed to a difference in liability to the disease processes, either due to the constitutional organization or to the environment or both.

In all events it is on these fatal conditions for which a difference between the sexes is noted and on the possible elements involved that the attention must be directed. The social behavior, differing as it does between the two sexes is obviously a factor of the utmost importance. Its effects on the mortality from accidents are unquestionable and are also accepted relative to cancer of the skin. The peculiar social function of the male may probably be responsible for some of the excess male mortality from alcoholism and suicide and also from duodenal and stomach ulcer as well as from appendicitis and from acute infections such as pneumonia.

The direct influence of the structural and functional differences of the primary and secondary sex organs on the mortality of the two sexes is also a factor of great importance. Among its principal manifestations are, of course, the morbidity and mortality associated with pregnancy. In addition, the liability to certain urinary diseases is also associated with the shape of the genitalia. Another manifestation of the differences in mortality between the males and females that can be attributed to the differences in the function of the sex organs is probably the higher fatality of the females from diseases of the thyroid and other endocrine glands, all of which are intimately related to the gonads. In this respect, the well-known effects of sex hormones on the experimental production of mammary cancer need not be emphasized. Even more significant when completely confirmed are the observations recently reported by Campbell (1939) concerning sex hormones and infections. Ordinarily, the degree of infection by *Cysticercus crassicollis* is in the female rats from 60 to 80 percent of that found in the males. By injecting theelin Campbell apparently increased the resistance of the male to equal that of the female, while in the latter no change was noted, on the average. The results were reversed when testosterone propionate was administered to rats of the two sexes.

Finally, between the males and females, there is the element of difference which is the resultant of their respective and distinctive constitutions, and is expressed by diversity in rate of metabolism, as Riddle (1932) has repeatedly shown and emphasized, and in rate and pattern of organic growth. The fact, as has been pointed out above, that in certain instances diseases of different etiology but causing a break-down of the same organ all tend to have the same type of sex difference, i.e. either a higher or a lower masculinity, suggest that the developmental factor may play a more important part than is generally recognized, particularly in relation to heart disease. One is encouraged in such a view by the results of the investigation of Klein and Palmer (1938) on the differences in the rate of dental caries among boys and girls. These authors found that at equal chronological ages girls experience more dental caries than boys. On the other hand, the eruption of permanent teeth also occurs earlier in girls so that the authors were moved to inquire whether at equal tooth age girls still have a higher caries rate. When the caries rate was actually computed in this fashion, no appreciable diversity in caries incidence would be detected between the boys and girls. Therefore, the authors conclude

that the girls have an apparently higher caries rate simply because their teeth have a longer exposure to risk. Bearing on this point it should be recalled that the growth of the majority of organs proceeds at a rate and with characteristics that are not the same in males and females, and that this is a phenomenon limited not only to man.

In conclusion, the fact that the males and females—two groups of individuals who in general differ in somatic as well as in physiological attributes—exhibit diverse reactions to pathogenic conditions not because of one but for a variety of reasons opens the way to investigate in a comprehensive manner the fundamental factors responsible for the individual variation in susceptibility and resistance to pathogenic processes. Since in other animals besides man sex differences in mortality are to be observed and since for other animals also there exist behavioristic as well as physiological diversities between the males and females, it would seem that a deeper study of the sex differences in mortality and morbidity approached either through animal or human biology would serve to contribute a more precise evaluation of the fundamental factors involved in health and disease.

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PHYSIOLOGY AND THE ORIGINS OF THE MENSTRUAL PROHIBITIONS

By M. F. ASHLEY-MONTAGU

Department of Anatomy, Hahnemann Medical College, Philadelphia, Pennsylvania

THE conception of the nature of menstruation and the prohibitions which are usually associated with it are remarkably similar in almost all human groups. Whether this may be taken as yet another illustration of the uniformity of the human mind, or alternatively, as evidence of a complex of beliefs having some common cultural origin, it is unnecessary to inquire here. Briefly, the menstrual discharge is most generally conceived to be a peculiarly noxious effluvium which automatically renders everything unclean with which it comes into contact. That being so, the female during her catamenial flow is considered to be herself unclean and as noxious as the effluvium itself. She is therefore usually segregated until the cessation of the catamenia or until some prescribed time following its termination, whenafter she customarily undergoes a ritual cleansing or purgation, following which she may once more resume a normal social life among her people. Anything she may have touched during the catamenia must either be destroyed or purified. Detailed discussions of the folkloristic and related aspects of this subject are to be found in the works of Briffault (7), Ellis (13), Frazer (19), Lévy-Bruhl (34), Ploss, Bartels, and Bartels (45), and Westermarck (57). In *The Old Testament* may be found the type expression of these beliefs and practises. One may here recall the first verse from *Leviticus*, Chapter 15, Verses 19 to 33: "And if a woman have an issue, *and* her issue in her flesh be blood, she shall be put apart seven days: and whosoever toucheth her shall be unclean until the even." (33).

An old rhyme puts this viewpoint very neatly:

> "Oh! menstruating woman, thou'rt a fiend
> From which all nature should be closely screened."

This charming rhyme is quoted without statement of source in a work by Milne (42). It would be of some interest to know its origin.

In *The Natural History* Pliny (44) interestingly presents the Roman viewpoint. He writes:

> It would indeed be a difficult matter to find anything which is productive of more marvelous effects than the menstrual discharge. On the approach of a woman in this state must will become sour, seeds which are touched by her become sterile, grafts wither away, garden plants are parched up, and the fruit will fall from the tree beneath which she sits. Her very look, even, will dim the brightness of mirrors, blunt the edge of steel, and take away the polish from ivory. A swarm of bees, if looked upon by her, will die immediately; brass and iron will instantly become rusty, and emit an offensive odour; while dogs which may have tasted of the matter so discharged are seized with madness, and their bite is venomous and incurable.

Elsewhere in the same work Pliny (44) repeats what he terms the "ravings", and which we may term the superstitions, of his age "of a most dreadful and un-

utterable nature" relating to the remedial and miraculous effects of which the menstrual discharge was supposed to be capable.

These, indeed, are for the most part nothing but ravings, and we need not consider them here except to say that a large number of the beliefs that Pliny describes may be found still persisting today in many parts of Europe as well as in many other regions of the world. An extremely large number of superstitions are associated with menstruation, and one of the most deeply entrenched of these which has for many generations enjoyed the status of a demonstrated truth, namely, the relation of the catamenia to the lunar cycle, has only very recently been shown, by Gunn *et al.* (23), to be totally without foundation. This demonstration, it may be added, being successfully carried out in spite of the elaborate theory of Gerson (21), an over-enthusiastic psychoanalytic writer, that menstruation probably became established as a biologico-lunar function as a consequence of the sport indulged in by primitive man of hunting his females on moonlit nights. The resulting anticipatory uterine hyperemia of the female over the course of many such moonlit nights, Gerson suggested, eventually developing into the overt bleeding of menstruation!

One of the oldest beliefs concerning menstruation is that the touch of a menstruous woman is capable of causing flowers and other plants to wilt and wither, preserves of every sort to spoil, dough to fail to rise, seeds to become sterile, meat to decompose, and so on. In many parts of Europe menstruous women are excluded from certain occupations. In the great French perfumeries, for example, women are not permitted to work during the time of their menstruation; nor are they allowed to pick mushrooms in those regions in which their growth is a profitable industry. In the south of France at such times they are not allowed to tend silkworms, and in the various wine districts of France and also of the Rhine women are debarred from approaching or handling the vessels in which fermentation takes place for the reason that should their courses begin, fermentation would be accelerated and the wine spoilt. For similar reasons, according to Laurent (31), women are excluded from the sugar refineries of northern France. The prohibition with respect to the handling of wine is incidentally clearly stated in the *Talmud* (*Midrash Wayyiqrā*) in the tale of Rabbi Gamliel and the maid-servant Fabritha. In this connexion the subject is discussed by Wünsche (59), and referred to by Spivak (54).

That women are physiologically in a peculiar state during the catamenia must have been fairly obvious from the earliest times; apart from the subjective evidences apparent to the woman herself, there are the important occasional mental disturbances, the so-called menstrual psychoses. There is some evidence that these mental disturbances have played a significant part in determining particular cultural viewpoints relating to the menstruous woman. Vidoni (56), for example, reports the record of a mediaeval Council which actually met to discuss the question as to whether or not a woman was to be held responsible for her actions during the catamenia. Tuttle (55) has experimentally shown that women undergo significant changes in irritability during menstruation. Novak (43), who has reviewed the evidence, points out that epileptiform states have frequently been found to coincide with or even to replace the catamenia. The association of menstruation with certain forms of hysteria is clinically well known. This associa-

tion is, of course, of considerable interest in our present connexion, and it may be recalled that the ancient belief that hysteria originated in some affection of the womb is epitomized in the very word *hysteria*, which is derived from the Greek word for womb, namely ὑστερα. Malodorous breath, increase in amount of sweat and its odour, skin eruptions of various kinds, respiratory disorders, among many other conditions which one may find reviewed in such a standard gynecological treatise as that by Graves (22), represent some of the well-known changes which occur during the menstrual period. Such conditions form a good foundation for believing almost anything of the menstruous woman, and would certainly lend some support to the suggestion that at such times she is capable of exerting a noxious influence upon the objects with which she comes into physical contact. The changes which occur within the female during menstruation are not by any means fully understood, but recently Bartelmez (4) in an admirable paper, which inspired the present paper, has reviewed some of the physiological theories and investigations relating to the alleged effects of menstruous women upon various living tissues. Bartlemez appears to have been the first scientist to have taken this matter seriously enough to make an attempt to bring the relevant evidence together. Unquestionably many of the conditions attributed to the menstrual woman are purely mythological, but the important point is that some of them are not, and it is not always easy to disentangle the true from the false. Something of the difficulty is illustrated by a recent experience of the present writer who, during his inquiries into this subject, was independently informed by a number of cultured women that many "beauticians" advise against a visit to the beauty shop during the menstrual period, because during that period a so-called permanent hair-wave will not 'take' as well as during the intermenstrual period. Satisfactory confirmation of this view could not be obtained from several beauticians consulted upon this matter. Nonetheless, it is quite possible that there may be a modicum of truth in the statements obtained from the clients of beauticians. It is well known that the bio-electric potential of the body differs from the normal conditions during menstruation, as recently shown by Burr and Musselman (8), and this, in some way, may possibly be related to the alleged menstrual hair-wave phenomenon. It is a subject which would bear investigation. However this may be, the supporting evidence for the belief in the menstruous woman's capacity for producing noxious effects upon living tissues is by no means contemptible, and in popular superstition, as well as in industrial centers in many places, the belief is, as we have already seen, solidly entrenched. Thus far these beliefs have enjoyed no more status than that which is usually granted to any folkloristic belief by those who are said to know better, but within recent years a gradually increasing body of experimentally controlled evidence has become available which renders it highly probable that there is actually a physiological basis, a foundation in fact, for these beliefs, and it has even been suggested by Macht and Davis (37) that such findings may explain the origin of the menstrual superstitions and prohibitions of primitive peoples. It is this latter possibility which it is proposed briefly to examine in this paper. Before doing so it is necessary to give an account of the kind of evidence which would appear to prove that menstruous women are capable of exerting some, at least, of the noxious effects which popular

superstition has for so long attributed to them.

It was not until as late as 1920 that Schick (51) first succeeded in arousing some scientific interest in these matters. Schick noted that various kinds of freshly cut flowers will wilt in anything from 10 to 20 minutes after handling by certain women during the first two days of the catamenia. Having found that the menstrual discharge itself exerts the same effect he postulated the excretion of a menstrual toxin or "menotoxin" during menstruation. In addition he found that systemic blood and axillary sweat during menstruation were more toxic to blossoms and retarded the growth of yeast more appreciably than at other times. Soon after Frank (18) confirmed this by placing flowers in a solution of menstruous woman's milk, and observed that the flowers wilted significantly earlier than flowers placed in a solution of non-menstruous woman's milk. This investigator very pertinently cited the prevalence of various disturbances in infants during suckling by a menstruous woman, a fact confirmed by the observations of Fraenkel (17), Silber (53), Eltz (14), and Borsarelli (6) among others. The idea of the existence of a menotoxin has found support among many clinicians for the reason, among others, as Aschner (1, 2) has pointed out, that during menstruation every organ of the body may be disturbed and every existing pathological or abnormal condition exacerbated. Sänger (50) was unable to confirm Schick's findings, but he is thus far the only investigator who has failed to do so. Levinson (32) has found that menstrual serum when injected into guinea pigs is more toxic in its effects than normal human serum. Macht and Lubin (38) obtained similar results for *Paramecia*, trypanosomes, and goldfish. Sieburg and Patzschke (52) have observed slowing of the frog's heart beat and an increase in the intestinal tone of the rabbit when exposed to the axillary sweat of menstruous women. These investigators consider the active agent to be choline. Labhardt (29) using the same methods reports much greater variability, incidentally finding the sweat of some men as potent as that of any menstruous woman! Polano and Dietl (46) find that the growth of yeast may be retarded or accelerated after being kneaded by menstruous women. They suggest that cyclic fluctuations in the traces of choline and creatinine excreted in the sweat from the finger tips is the responsible agent. It is of interest to recall here that in the course of a discussion, which took place in the pages of *The British Medical Journal* in 1878, concerning the alleged deleterious effects exerted by menstruating women on the cure of meat, one correspondent, R. B. F., made a similar suggestion, offering as an explanation for the phenomenon "the moisture that is on the hands and body during the catamenial period" (15), a suggestion which, in the same issue of the journal, was treated with derision by the editorial writer. Both Novak (43) and Briffault (7) quote this discussion as exemplifying the persistence of such superstitions 'even' among medical men. It may be so, but as Hull (26) has remarked "The superstitions of today were the serious beliefs of yesterday, and as such they demand from us both study and respect." Klaus (27) by gravimetric determinations of choline in sweat by the platinic chloride method computes that 312 mgm. of choline per liter occurs in menstrual or immediately pre-menstrual women as compared with 6.5 mgm. in intermenstrual women, and only a trace in men. Later Klaus (28) sought, but failed, to find choline in the discharge

itself. The odour of the discharge, however, indicates trimethylamine, and tests for it during menstruation, and also it may be noted during the intermenstruum, are positive. Klaus suggests that choline eliminated during menstruation is broken down into trimethylamine or a similar substance. In this connexion it is of great interest to recall here that as long ago as 1902 Michin (41) had already shown that in normal women the quantity of trimethylamine varied between 0.07 per cent to 0.72 per cent with a mean of 0.33 per cent. In women with various genito-urinary disorders the range was from 0.00 to 0.64 per cent. Michin very significantly found that trimethylamine was altogether absent from the secretions in post-climacteric women, and moreover that it was strongly bactericidal as well as tumor-activating in its action. The present writer has elsewhere given a brief account (3) of Michin's findings. Czapek (11) has shown that trimethylamine accumulates in the sexual organs of many plants and animals; and quite recently Havas (25) has demonstrated the sex-hormone like properties of trimethylamine, as well as its bactericidal and tumor stimulating properties. Sieburg and Patschke (52) found that choline had no demonstrable effect upon cut flowers, and Macht and Lubin (38) similarly found that choline was not very toxic for various plants. Klaus (28) failed to find evidences of choline in the discharge itself, and Cattaneo (9) failed to find any traces of this substance in the human uteri examined by him. On the other hand Lánczos (30) has found that a preparation of frog's gastrocnemius muscle loses excitability when either the nerve or the muscle is held by a menstruous woman for 10 or 15 minutes, and that dilute solutions of trimethylamine have the same effect. Macht and Lubin (38) believe menotoxin to be an oxycholesterol. These investigators found that blood serum, blood corpuscles, saliva, sweat, milk, tears, and urine of menstruous women produce inhibition of fermentation by yeast; that the mere handling of yeast by a menstruous woman is sufficient to produce wholesale destruction of these microscopic plants. They found also that these substances produce retardative and toxic effects in *Paramecia* and trypanosomes, causing withering of freshly cut flowers, inhibiting the geotropic properties of lupine seedlings, inhibiting protoplasmic streaming of certain plant cells, and generally producing a depressant effect upon plant and animal tissues. Macht and his various co-workers (35, 36, 37, 38) have repeatedly confirmed these findings in a number of studies, and these have for the most part been confirmed by a large number of other investigators. Böhmer (5) has obtained similar results by the use of the same methods and has found that similar toxic effects are produced by the menstrual discharge when the vulval secretions are included. Dogliotti (12) using the discharge obtained directly from the uterus failed to observe any effects on frog's heart or neuromuscular preparations or on arterial pressure in the dog. Mandelstamm and his co-workers (39) using the phytotoxic method found no evidence of retardation of growth of seedlings by menstrual discharge removed from the uterus, by blood, or blood serum, but they did obtain a slight effect by using the vulval discharge. Macht (35) found that menstrual serum delayed the coagulation time of dog's and human blood, and the same investigator (36) by means of a special method devised by him, a method which yields a phytotoxic index (i.e., the ratio of the growth of the roots of *Lupinus albus* seedlings immersed in a solution containing the unknown

menotoxic factor to the growth of the roots of the untreated controls), has shown that normal blood sera (derived from "several thousand" samples) in 1 per cent solution yields an average phytotoxic index of 75 per cent—complete theoretical atoxicity being taken as equal to an index of 100 per cent. Menstrual blood sera yields the high phytotoxic index of 51 per cent, an index which for toxicity is so far as is at present known exceeded only by the blood sera of the grave diseases such as pernicious anaemia, leprosy, and trachoma, with phytotoxic indices respectively of 44, 47, and 48 per cent. Meyran and Nothaas (40) have shown that any blood serum has an inhibitory effect on lupine seedlings, and observed a significant retardation from the blood only of 4 out of 23 menstruating women. Such a finding suggests the existence of significant variations as between different individuals. Freeman and Looney (20) have been unable to find any significant difference in the degrees of toxicity of menstrual and intermenstrual blood; the phytotoxic indices obtained by them on 22 normal women being respectively 53.2 and 53.9 per cent. Fleckner (16) has found that systemic blood will produce the same effect upon plants as menstrual discharge when added to the nutrient solution in which they are growing. He also finds that the discharge like the blood when added to the water used on plants growing in earth serves simply as manure. Among the most significant studies thus far carried out on the effects of menstrual discharge and saliva is that of the botanist Christiansen (10) who found that menstrual discharge from cervix uteri and vagina produced either retardation or acceleration of growth in yeast and also in the bacteria producing coagulation of milk. Christiansen also found that saliva from a menstruous woman invariably inhibited fermentation. Important seasonal variations were observed in the effects produced by the menstrual discharge. Interestingly enough Christiansen found that an emanation from the menstrual discharge was capable both of killing and inhibiting the growth of yeast cells at a distance, and he suggests that this effect may be due to the action of mitogenetic rays. Rahn and Barnes (48) have repeated and confirmed Christiansen's work, and emphasize the probable rôle played by mitogenetic rays in the production of the observed effects. Rahn (47) has discussed this subject in some detail in a later work. Rahn and Barnes (49) found that oxycholesterol killed yeast cells through quartz, but Macht and Davis (37) were unable to obtain any effect on *Lupinus albus* seedlings when a menstruous woman's hand contained in a quartz vessel was immersed in the nutrient solution; the unprotected hand, however, when immersed in the solution for only a few minutes produced a definite inhibitory effect.

Without here entering into any discussion of the nature of the substance which is secreted by women during menstruation, and which may be the responsible agent in producing the effects upon living tissues described above, it may be said that the evidence strongly points to an alkylamine, most probably trimethylamine. It has long been popularly recognized that the characteristic odour emanating from the female vagina and that which arises from decomposing fish bear a great similarity to one another; but while the odour of decomposing fish has long been known to be due to trimethylamine the origin of the odour emanating from the human vagina has remained undetermined. Woodward and Alsberg (58) point out that the volatile alkylamines which occur

in foodstuffs may in most instances be taken as an index of decomposition. Hanna *et al.* (24) have shown that the stinking smut of wheat—which has an odour identical with that which emanates from the human vagina—is due to trimethylamine. In view of the demonstrated effects of trimethylamine described above upon various tissues, it seems reasonably probable that the substance secreted by menstruous women which is responsible for the effects described is either trimethylamine or else a substance the decomposition product of which is trimethylamine.

In any event, the experimental evidence cited in this paper is sufficient to show that menstruous women are capable of exerting a noxious effect upon various living things with which they may come into contact. The question we now have to consider is what possible bearing such facts can have upon the origin of the prohibitions which are almost universally associated with menstruation. The suggestion is that at some period in the history of human society it was noted that certain deleterious changes produced in living things were associated with the presence of menstruous women, and that the inference was drawn that women in their periods were responsible for these undesirable effects; consequently in order to prevent such effects from occurring a prohibition was put upon women during their menstrual periods. This observation may have been made once or independently by different groups at different times. Primitive man is an extremely good observer, so that on the score of his observational powers alone the observation of such a relationship is by no means inconceivable, and though he may subsequently come to attribute the noxious effects of the menstruous woman to the operation of supernatural or magical factors, that would not detract one whit from his ability to perceive the existence of a significant relationship and a necessary association.

There is a danger in this kind of reasoning which we must be careful to avoid—it is the danger of intellectualization. Twentieth century science appears at last to have discovered that menstruous women excrete substances which are capable of exerting a harmful effect upon living tissues of certain kinds. Primitive man has believed that women are so capable for countless centuries. Science, as the result of experimental investigation, attributes the capacity to the operation of certain chemical and physiological factors—primitive man to the operation of supernatural or magical ones.

The only question which we have to consider is whether the menstrual prohibitions of primitive man are based upon an observed relationship not clearly understood but about which a great explanatory edifice of myths and magical beliefs have been erected, or whether the menstrual prohibitions have their origin in an irrational or supernatural conception of the nature of menstruation quite apart from any observed relationship between an apparent cause and a necessary effect.

To such a question, or questions, it is clearly impossible to return a definite answer since it is historically quite impossible to know what actually generated a group of beliefs of this kind in the various parts of the world in which we find them. The same kinds of prohibitions and practises may have had numerous independent origins in different human groups, or they may have had but few, or even a single one. We do not know, and the present beliefs of primitive peoples relating to menstruation do not afford us much assistance in this connexion. The suggestion that these prohibitions origi-

nated in the recognition of an observed relationship similar to that which scientific investigation has recently proven to hold good can neither be proven nor disproven, nor can any evaluation of probability be made in respect of it. It must remain what it is—an interesting suggestion.

In favour of this suggestion there is this to be said: In most primitive human groups of which we have any knowledge the gathering of food and the practise of elementary agricultural processes are activities which more often than not are restricted to women. Such an association provides a favourable set of conditions for an observation such as Schick (51) was able to make in connexion with the freshly cut flowers that were handled by the menstruous women in his office. It requires to be pointed out that food-gathering and agricultural peoples live under conditions which necessitate close attention to, and observation of, every aspect of these most important of economic activities. These are matters upon which their very lives depend, and about which, for the most part, their lives revolve; hence, it is by no means inconceivable that such an observation as that menstruous women exert a detrimental effect upon the growth of various plants was at some time in some human group or groups made, and this in turn made the basis of the menstrual prohibitions. But this is a pure speculation.

SUMMARY

The experimental evidence for the suggestion that menstruous women are capable of exerting a deleterious effect upon living tissues is surveyed with special reference to the origins of the menstrual prohibitions.

It would appear that menstruous women are capable of exerting noxious effects upon many living tissues.

The indications are that a substance, excreted through the hands during menstruation, is the agent responsible. The evidence points to an alkylamine, probably trimethylamine.

The possible physiological origin of the menstrual prohibitions is discussed, and it is shown that definite conclusions in this connexion are impossible.

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NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of Biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to Dr. Raymond Pearl, Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *1901 East Madison Street, Baltimore, Maryland, U. S. A.*

BEGINNING A NEW INVERTEBRATE ZOOLOGY

Being a review of *The Invertebrates. Protozoa through Ctenophora* by Libbie Henrietta Hyman. *New York and London* (McGraw-Hill Book Company), 1940. Pp. xii + 726. $7.00.

By Thomas Park, Hull Zoölogical Laboratory, The University of Chicago.

Invertebrate zoölogy is a field so vast, so pregnant with interesting problems and so poorly synthesized in a critical sense that the appearance of an initial volume of a series on this subject demands careful scrutiny. The zoölogists have been hard pressed to get coordinated, yet recent, information about the invertebrate phyla. In fact, they still find it imperative to consult such dignified but pristine stand-bys as the *Cambridge Natural History* (1895–1909); Lankester's never-completed *Treatise* (1900–1909), and Bronn's *Klassen und Ordnungen des Tierreichs* (1880—). Of later years such books as Kükenthal-Krumbach's *Handbuch der Zoologie* (1923—) and several others have been available. But the American and British biologist needs a treatment in English that will be contemporary, authoritative, well-documented and in good prose. Judging from the first volume, Dr. Hyman's *The Invertebrates* (1940) will fulfill these desiderata and thereby come to occupy a unique position on biological bookshelves. The first volume is a beginning. The author, after presenting certain general concepts of morphology, develops and defends a schema of classification and phylogeny and then proceeds to discuss in detail, and with mature appreciation of their variability, the Protozoa, Mesozoa, Porifera, Cnidaria (Coelenterata) and Ctenophora. This book would appear of enough importance to warrant special mention in these columns.

Although Chapter II (Classification) occupies only 22 pages of the total 726, nevertheless it will be of great interest to the zoölogist. Here, Hyman reviews historically the principal classificatory systems of earlier workers and, from this background, weaves her own pattern of arrangement. Some of the features of this pattern can be seen in Figure 1 which is a copy of a phylogenetic tree sponsored by Hyman. Study of this diagram brings out a series of interesting points.

PHYLOGENETIC RELATIONSHIPS OF ANIMAL PHYLA ACCORDING TO THE VIEWS OF HYMAN

1. Hyman is concerned with three important categories of animals: the "Acellular" forms or Protozoa; the "Radiata" or Coelenterates and Ctenophores, and the "Bilateria" or bilateral animals.

2. The flagellate protozoa are considered ancestral to other protozoa, sponges and a planula-like metazoan. Presumably, the flagellates also serve as a link connecting animals with plants. This treatment of the Protozoa will indubitably find welcome support although certain zoölogists

will quarrel with the implication of the term "acellular" when used in this connection.

3. The planula is placed in an important phylogenetic position as an early metazoan prototype presumably of a gastrula-like level of differentiation. This view has found corroboration recently in the careful analyses of Snodgrass (1938, *Evolution of the Annelida, Onychophora, and Arthropoda*).

4. From the planula two major lines of evolution originate. One line moves towards a primitive medusa and culminates in the Radiata. The other line develops towards a bilateral metazoan that Hyman views as a primitive flatworm lacking, of course, a body cavity.

5. The bilateral animals are treated in a di-phyletic manner. The group is dichotomized into the Protostomia and the Deuterostomia. This follows the proposals of a number of earlier investigators; particularly the Germans, Goette (1902), K. C. Schneider (1902), Grobben (1908) and Hatschek (1911). The Protostomia are those bilateral animals in which (a) the blastopore becomes the mouth; (b) the mesoderm originates from embryonic pole cells or masses, and (c) the cleavage is of the determinate type. The Deuterostomia are those bilateral animals in which (a) the mouth in a new formation; (b) the mesoderm originates as pouch-like evaginations of the gut wall, and (c) the cleavage is of the indeterminate type.

6. The Protostomia are broken down further on the basis of the origin and structure of the body cavity. Thus, Hyman recognizes those forms with no coelom (Acoelomate); those whose body cavity is a remnant of the embryonic blastocoel (Pseudocoelomate), and those which have a body cavity arising as a space (delamination) in the mesoderm (Schizocoela). The chart suggests that the flatworms and nemertean worms are partners in a common origin, namely, a primitive flatworm stock. Another line of evolution has led to a diverse pseudocoelomate group the Aschelminthes (Rotifera, Gastrotricha,

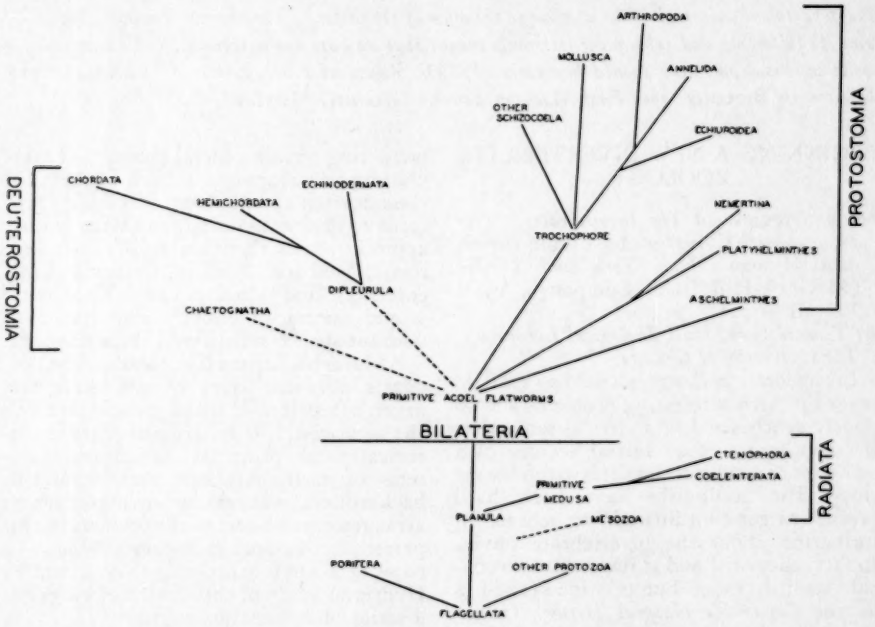

FIG. 1

Kinorhyncha, Nematoda, Nematomorpha and Acanthocephala) and the Entoprocta. The splitting of the latter from the Ectoprocta (Bryozoa or Polyzoa) is an excellent decision. The schizocoels are truly coelomate and consist of those forms that have evolved from some type of trochophore-like larva. This assumes that the trochophores, wherever found, are fundamentally homologous stages and thus do not represent convergent or caenogenetic evolutions. As with all earlier authors, Hyman has difficulty in evaluating the Brachiopods. She finally places them with the trochophore-protostomia. This is merely a concession since, as she recognizes, they have a coelom that arises as an outpocketing of the archenteron (enterocoelous).

7. The Deuterostomia probably also originated from primitive flatworms although the evidence for this view lacks cogency. On the basis primarily of echinoderm embryology and the morphologic similarities (homologies?) between echinoderm and Tornaria larvae, Hyman conceives of the hypothetical "Dipleurula" larva as a bilateral, enterocoelous prototype of the Echinodermata and Hemichordata. Again, this is not a radical departure from a great deal of current opinion.

8. In sum, it would appear that Hyman's phyletic treatment is about as good a historical document as can be assembled at the moment. It fits a series of correlated facts fairly well and has the virtue of relative simplicity. Patently, any such device is replete with many scientific pitfalls. This is a point recognized by all careful zoölogists. In fact, from a methodological aspect such efforts even may not fall into the category of science. Despite all this, most zoölogists find a certain amount of phylogenetic speculation entertaining and useful mental falderal. Snodgrass puts it neatly when he says, ". . . Every biologist must have a working creed of phylogeny, but he should not too implicitly believe its tenets."

In this review a disproportionate amount of time has been put purposely on phylogeny. Hyman passes through this discussion with economy and dispatch. The pragmatic value of the book lies in its excellent treatment of the Protozoa, Mesozoa, Porifera, Coelenterata and Ctenophora. Happily, the type method of presentation has been eschewed. Thus the reader learns that there is more to the protozoa than *Amoeba* and *Paramecium* and to the Coelenterata than *Hydra* and *Obelia*.

In the actual presentation each phylum is given a chapter consisting of the following material: Characters of the phylum; Classification of the phylum; General morphology and physiology; a detailed treatment of each class; General and phylogenetic considerations, and a superlative bibliography arranged primarily according to major systematic categories. Under phylum characters Hyman first reviews certain highlights that stand out in the historical development of knowledge about the group. This is followed by a definition of the phylum as a natural biological population. The section on classification deals with taxonomic categories of the rank of sub-order or above. This treatment is more than a mere roster of names since diagnostic features are given for each name presented. This can be illustrated by an example chosen at random among the Anthozoa:

> *Order 5.* Gorgonacea, the horny corals, gorgonians, sea fans, sea feathers, etc. With an axial skeleton of calacreous specules, or of gorgonin, or of both; polyps short, equivalent, rarely dimorphic, borne on the sides of the skeletal axis, not reaching the base. (p. 371)

Throughout the book Hyman has treated all questions of terminology rigorously. If the preface she says,

> . . . I have made an earnest effort to bring order and clarity into the confusion of zoölogical terminology; to define each term precisely and to adhere to that definition; and to eliminate homonyms. . . . I have not hesitated to drop established terms when they appeared to me inept or confusing and have boldly coined new terms when these seemed to be badly needed.

In the general morphology and physiology sections a clear picture is developed of the biological constitution of each phylum. Within the limitations of present knowledge, the reader gets a good insight into just what constitutes a protozoan or a cnidarian and how such forms carry on many basic operations. There is also some information about special problems such as encystment, regeneration and genetics

for the Protozoa; regeneration and the problem of individuality for the sponges; nematocyst activity and metagenesis for the Coelenterata, and so on. The same mode of attack, on a more detailed plane, is followed in the discussion of each class. The phylogenetic material is a useful summary of intra-phylum relationships.

From the technical aspect the book is well prepared on the whole. The type is readable and the binding is good. There are 221 carefully selected figures that illustrate points made in the text. The book has a good subject index but lacks an author index. It is unfortunate indeed that the latter was omitted for it would have been highly useful to the reader and student. As in any undertaking of this magnitude certain errors and omissions have crept in. But they are trifling and it would be pedantic to enumerate them here.

A first-rate reference text gives the discriminating reader the feeling that the author (1) knows, and has made good use of, *original* literature sources; (2) is thoroughly familiar with much of the *actual material*, and (3) has thought about the subject matter with trenchant perspective. It is a pleasure to report that books of this calibre on various phases of invertebrate zoölogy are increasing. The past few years have produced such scholarly efforts as *Principles of Insect Morphology* (Snodgrass; 1935) and *Principles of Insect Physiology* (Wigglesworth; 1939). Hyman's, *The Invertebrates* (first volume) takes its place along with these. Zoölogists will await impatiently Book II of the projected series.

BRIEF NOTICES

EVOLUTION

THOUGHTS ON EVOLUTION. *III. Evolution and the Primitive. Anthropological Series of the Boston College Graduate School, Vol. IV, No. 3.*

By Joseph J. Williams, S.J. Boston College Press, Chestnut Hill, Mass. $1.00. 9½ x 6½; 64; 1939 (paper).

In this study the author considers evolutionary theories which have been proposed on the origin of man and the origin of monotheistic religion as related to the dim past of *Homo sapiens*. He sets forth the theories of well-known scientists and calls attention to the many contradictory reasonings contained therein. The author's object is to

> determine whether a careful analysis of the facts collected show that there has been within historic times an evolutionary influence or a decadent one, directing the affairs, religious and otherwise, of the so-called Primitives of Africa, and in consequence to establish whether the theories built up by Evolutionists on their present culture are founded on objective evidence or solely on subjective preconceptions.

A second article is a pictorial and word description of the flint artifacts of the L'Abri Bergy site, of which a general description was given in the April issue of the *Anthropological Series*.

LEAVES AND STEMS FROM FOSSIL FORESTS. *A Handbook of the Paleobotanical Collections in the Illinois State Museum. Popular Science Series Vol. I.*

By Raymond E. Janssen. Illinois State Museum, Springfield, Ill. $1.25. 9¼ x 6¼; 190; 1939 (paper).

This beautifully illustrated report is based mainly on the fine Langford collections of fossils taken from the Mazon Creek coal region of Illinois—although these same forms are to be found elsewhere in the state. Something over 150 genera and species are described and illustrated (164 figures, mostly photographic reproductions). The 16 different coal seams to be found in Illinois indicate that for 16 consecutive times the water rose and destroyed and buried the luxurious tropical vegetation which covered this region. The preservation of the remains is such that, in the shale beds immediately above or below the coal seams, complete leaves with their intricate veins, surface hairs and texture, and individual plant cells can be studied. A bibliography and index complete the report.

GENETICS

THE GENETIC BASIS FOR DEMOCRACY. *A Panel Discussion on Race and Race Prejudice. Held at the Little Theatre, Hall of Science and Education, New York World's Fair, October 14, 1939.*

By Henry A. Wallace, Franz Boas, Hadley Cantril and William A. Hamm. American Committee for Democracy and Intellectual Freedom, 519 West 121 St., New York. 40 cents. 11 x 8½; 25; 1939 (paper).

The average person who dislikes foreigners or racial groups other than his own is likely to think that he does so because they are inferior in some way. But the fact is that more often than not such a person has got the cart before the horse. The fact that he dislikes them is the cause for his thinking them to be inferior. It is a simple matter for the geneticist to show that there is little or no scientific basis for theories of racial inferiority, but that is not enough. The old poem about Dr. Fell carries more weight with the "morally illiterate" (this apt phrase is quoted from Mr. Hamm's contribution to this panel discussion) than all the conclusions of the scientists.

Of the four contributions to this symposium, three are exclusively diagnostic. Only one, that of Cantril, is prescriptive. He mentions by name several subversive organizations (the list might easily be made more comprehensive) whose methods and sources of propaganda might be investigated to advantage. He also warns of the flood of anti-alien (and therefore un-American in spirit) legislation that will undoubtedly try to force its way through Congress if that body should exercise its prerogative of declaring war, and suggests preparations to oppose it.

Twenty-three years ago there was only one organization in the United States concerned directly with the preservation of intellectual freedom. That there are so many more today is a sign of hope and a cause for thanksgiving.

PARTNER OF NATURE.

By Luther Burbank. Edited and transcribed by Wilbur Hall. D. Appleton-Century Co., New York and London. $3.00. 8 x 5½; xi + 315 + 23 plates; 1939.

The life of Luther Burbank, both as a man and as a naturalist, should be an inspiration to everyone who has the slightest interest in the wonders of the plant world about him. This thoroughly enjoyable volume is essentially an autobiography, though the material has been compiled and edited since Mr. Burbank's death, and it deals only with his work—but then his work was really his life. Burbank admitted quite frankly that he had no literary talents, but he has succeeded in putting down clearly, forcefully, and in a delightfully readable and interesting fashion, the results of his long and rich life of work in practical plant breeding, propagation and experimentation. The underlying theme of his great work, and the note that he stressed again and again, was patience. To this he added the single factor of repetition.

The clue to his success in producing new fruits, vegetables and flowers, and improving our old ones is explained in Burbank's ability to learn what nature has to teach, and to use that knowledge in directing and speeding up the natural processes by which plant evolution has taken place. The value of his work can probably never be estimated in terms of dollars and cents. His improvements on the potato alone have resulted in an estimated increase in value of more than a billion dollars in the past fifty years!

The volume is not intended for the professional botanist but for the practical and amateur plant breeder, the nurseryman, and the back-lot gardener. The text is richly illustrated, and carefully indexed.

PRACTICAL PLANT BREEDING. *Second Edition.*

By W. J. C. Lawrence. With a Foreword by Sir Daniel Hall. George Allen and Unwin, London; De La Mare Garden Books, New York. 5s. 6d. net. 7¼ x 4¾; 155; 1939.

Mr. Lawrence's experience as director of the gardens of John Innes Horticultural Institution has well qualified him for the

task of writing this book on practical plant breeding. The separate enterprises of botany, genetics, and plant propagation have been adequately discussed in separate volumes, but the three have probably never before been so well synthesized for the purpose of laying the foundation for a study of plant breeding, as has been done in this volume.

The range of material includes discussions on the structure of plants and flowers, the techniques of cross-pollination, the laws of heredity, and the general methods of improving plants. The volume is simply written, free from technical terminology and textbook procedures. The numerous drawings, diagrams, and photographs will undoubtedly enhance the value of the book as a guide in the hands of the amateur gardener or nurseryman. An index and a selected list of books on plant breeding conclude the volume.

POPULATION, RACE AND EUGENICS.

By Morris Siegel. Published by the Author, 546 Barton St., Hamilton, Ontario. $3.00. 7½ x 5; x + 206; 1939.

Dr. Siegel divides his book into two parts —positive eugenics and restrictive eugenics. In the first he discusses population and eugenics and the probable etiology of differential fertility and makes recommendations for improving the situation. Much is said concerning racial theories in relation to eugenics and every effort made to deflate the claims of those who champion "Nordic superiority." There is a very helpful chapter on rational marriage from the eugenic point of view. In the second part of the book, the various mental aberrations of eugenic significance are discussed and restrictive measures proposed. There are bibliographies appended to each chapter and a good index is provided.

BIBLIOGRAPHY ON THE GENETICS OF DROSOPHILA.

By H. J. Muller. Oliver and Boyd, Edinburgh. 5s. 9¾ x 7¼; 132; 1939 (paper).

Students of the genetics and physiology of *Drosophila* will find this a highly useful publication. In addition to articles on this insect, the bibliography includes a few works which, although dealing with other forms, concern problems intimately connected with the field of genetic research. The material is presented alphabetically by authors and co-authors. Muller believed it inadvisable to provide a subject classification in view of the considerable amount of overlapping which this would necessitate. Titles in Eastern European languages have been translated into English and the original language indicated. Notes also appear which indicate summaries in languages other than that used in the body of the article. A number of abstracts, dissertations, and unpublished manuscripts are listed among the almost 3000 titles presented.

GENERAL BIOLOGY

ANNUAL REPORT OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION: *Showing the Operations, Expenditures, and Condition of the Institution for the Year Ended June 30, 1938. Publication 3491.*

Smithsonian Institution. U. S. Government Printing Office, Washington. $1.50. 9 x 5¾; xiii + 608 + 11 plates; 1939.

To the summary of the year's activities of the various branches of the Institution there is added, as usual, a general appendix containing papers (32 in the present volume) on a wide variety of subjects, but all of interest to the general reader. The writers, in each case, are dealing with their own special subjects in which they are authorities, hence write clearly and accurately. It is only possible, in so limited a space, to give briefly some of the topics presented: P. G. H. Boswell writes of The floor of the ocean; H. T. Stetson, The sun and the atmosphere; H. E. Wimperis, The natural limits to human flight; etc. Coming to the purely biological papers—in Eyes that shine at night, by E. P. Walker, we read that the cat is not alone in the shining of its eyes by reflected light. There are toads, of the genus *Bufo*, and the caiman (tropical American alligator) "whose eyes give perhaps the most

pronounced and beautiful glow I have ever observed." The eyes of most domesticated and some wild animals deteriorate in their reflecting ability in captivity. In some animals the color of the "shine" is constant, in others it may appear as three different colors within a few seconds. The paper on The black widow spider (reprinted from The Quarterly Review of Biology, vol. 11, No. 2, June 1936), by D'Amour, Becker and Van Riper, gives a great deal of information about this timid but much-feared insect. K. von Frisch, in writing on The language of bees, tells of training bees to color and to scent. Training to taste is impossible, "Either they [the bees] drink the solution or they refuse it." But the bees "have something like a language" and von Frisch reports some of the results of his many experiments along this line. We regret that there is not space to include some of the interesting facts brought out in such discussions as Forest genetics, The story of the maidenhair tree, "Root-pressure"—an unappreciated force in sap movement, the Folsom problem in American archeology, and others. Illustrations, maps and bibliographies frequently accompany the texts.

KOONWARRA. *A Naturalist's Adventures in Australia.*

By Charles Barrett. Oxford University Press, New York and London. $3.00. 8½ x 5½; xii + 315 + 49 plates; 1939.

The author of Koonwarra is a naturalist and traveler by choice, a newspaperman by profession. The name Koonwarra, meaning black swan, was chosen for the title of this book describing life on the smallest of all continents, because it has both historical and scientific significance. In 1697 William de Vlaming, a Dutch navigator, caused a furore in Europe by returning from the west coast of Australia with four swans which amazingly enough had plumage of black.

The author is most adept at spinning a yarn, and this book, which one could really call an autobiography, is full of amusing anecdotes. Not to mention beach-combers, blackfellows, bushmen, and sundry traveling acquaintances, Mr. Barrett's family, friends, fellow scientists, and even two old maid neighbors play their rôles in this entertaining book. The author has covered a great deal of Australian territory in his search for interesting plants, animals, birds, and insects. He describes his many journeys and what he has seen on his wanderings in Queensland, central, southern, northern, and north-western Australia, through the Bass Strait and its many islands, through the Gulf of Carpentaria and its islands, on Erye's Peninsula, in Tasmania, on the islands of the Great Barrier Reef, up and down inland rivers and lakes too numerous to mention. The reader is told of the habits, habitats, and geographical distribution of such varied creatures as the giant earthworm, spiny anteater, platypus, koala, bull-ant, cuccus, crocodile, wombat, tree kangeroo, cassowary, tiger-snake, python, blue-tongued lizard, lyre-bird, mutton-bird, oppossum, giant clam, and the hideous deadly stonefish. There is little which escapes the observation of this witty naturalist-newpaperman. Numerous full-page photographs and a very detailed index complete the book. The reader will regret the omission of a map showing the territory covered.

THE COLLECTED LETTERS OF ANTONI VAN LEEUWENHOEK. *Part I.*

Edited, illustrated and annotated by a Committee of Dutch Scientists. Swets and Zeitlinger, Amsterdam. 19 guilders (paper); 21.50 guilders (bound). 11⅜ x 8½; 454 + 39 plates; 1939.

This fine commemorative volume, the first of a series that will ultimately comprise 20 when completed, bears witness to the esteem in which one of the earliest biologists is held by his successors and countrymen. The leading scientific institution of the Netherlands, The Royal Dutch Academy of Sciences, jointly with the foremost society of scientific physicians have undertaken to publish in this series a complete critical edition of all of van Leeuwenhoek's letters that are obtainable. A second aim is to make the works and opinions of Leeuwenhoek in-

telligible to the modern reader. The editors perhaps put it best when they say, "Whoever reads a paper by Leeuwenhoek, even when it deals with a subject in which he specializes, cannot have absolute certainty about what Leeuwenhoek actually saw and described. An interpretation of Leeuwenhoek's observations is a science and art in itself."

The present volume contains the earliest letters written by Leeuwenhoek (21 in number, dating from April 28, 1673 to February 22, 1676). Letters addressed to Huygens, Leibnitz, Magliabechi, and many others are reproduced and many original drawings by Leeuwenhoek are used to properly illustrate the subject matter incorporated in the letters. The right-hand pages of the book are in English; the left-hand pages are in Dutch. The numerous explanatory footnotes accompanying the letters testify to the thoroughness with which the committee is going about its task.

The tables of weights and measures used by Leeuwenhoek (he was the first to measure microscopic objects and hence had to select objects which could serve as standards of comparison) and placed at the end of this volume is both of historical and practical value. The biographical register of persons mentioned by Leeuwenhoek in his letters is also of great interest. The volume contains an index of names and subjects, also an index of illustrations. The completed series will form a truly monumental work of great historical value.

A NATURALIST ON RONA. *Essays of a Biologist in Isolation.*

By F. Fraser Darling. Oxford University Press, New York; The Clarendon Press, Oxford. $2.50. $8\frac{5}{8}$ x $5\frac{1}{2}$; x + 137 + 28 plates + 1 folding map; 1939.

This book definitely adds to Fraser Darling's already solidly grounded reputation as a naturalist and a writer of distinction. North Rona is a tiny island off the northwest coast of Scotland. For human beings it is no gentle environment. But the Darlings (♂ and ♀), from experience and innate liking, know how to get the most out of life in such places.

> For us in our years of primitive life on three such tiny islands there has never been a dull day, though many an uncomfortable one. Our content has rested on maintaining a spirit of acceptance and having always more than enough to do—apart from goodwill within the family. I mean by a spirit of acceptance a tolerance of environmental conditions, whatever they may be, and a realization that it is no good trying to live by a routine. You must work when the work is there, and if on the next day a gale of wind and rain makes work impossible, let it be and turn your hand or mind to something else. This is the second point of having more than enough to do; I do not think anybody can be happy in the necessary restriction of island life unless there is an alternative and constructive outlet for one's energies. There has been for me on North Rona the writing of this book of essays of forest and island, in slack hours of high summer, on the impossible days of weather about the autumn equinox, and during long winter evenings when nothing could be done outside.

The content of the eight essays in this volume is reasonably well indicated by their titles: The vivid frontier; The display of birds; North Rona; The social life of animals; Ron Mor: the great seal; Sanctuaries for wild life; The mystery of antlers; Forest and island.

Altogether this is a book that every naturalist, ecologist, and animal behaviorist will want to read, for it contains much that is original and sound.

THE GREAT NATURALISTS EXPLORE SOUTH AMERICA.

By Paul R. Cutright. The Macmillan Co., New York. $3.50. $9\frac{1}{4}$ x $6\frac{1}{4}$; xii + 340 + 31 plates; 1940.

Perhaps there remains more unexplored territory in South America than in any other part of the world. There are of course larger areas of barren deserts of sand, snow, and mountain never visited by man; but the unknown recesses of South America are filled with plants and animals that are still new to science or imperfectly known. For the little knowledge that we do have we owe a great deal to those intrepid naturalists and missionaries who braved the rigors of the Amazonian jungle, Argentine pampas, and the mountainous Andes.

The author of this book presents the

important discoveries and observations made by the South American naturalists from the time of Alexander von Humboldt to such contemporary men of science as Murphy, Cherrie, Tate, Ditmars, and others. The reports of various observers on a particular animal are brought together, enabling the reader to get the true picture of the animal's peculiarities. Bats, sloths, monkeys, birds, snakes, crocodiles and the fierce piranhas are just some of the animals ably and interestingly reviewed in this way. Nor are the insects, the joy and bane of all South American explorers omitted. Good illustrations, a bibliography and an index, and especially an outline map of the continent on which to trace the routes of the great naturalists, complete this fine review of South American exploration.

A Forgotten River. *A Book of Peruvian Travel and Botanical Notes.*

By Christopher Sandeman. Oxford University Press, London, New York and Toronto. $5.00. 8½ x 5½; xii + 299 + 15 plates + 2 maps; 1939.

Here is a book that will make any field naturalist green with envy. It is a diary covering three months of travel in a part of Peru that had not been explored by a scientist since 1850. The author, a well-known botanist, had dreamed of making such an expedition for years.

The greater part of Peru lies east of the Andes, and consists of three parallel valleys draining into the Amazon. It is difficult to get from one valley to another without going outside the Peruvian boundary, but no one knows exactly where these boundaries are. Two of the valleys, those of the Marañon and the Ucayali, are well known, but that of the Huallaga is practically virgin territory for the field biologist.

The author and a friend crossed the Andes near Cerro de Pasco, whither they had gone on muleback from Lima, then made their way to the source of the river at an altitude of 14,000 feet, constructed a raft on which they descended to 597 feet near Yurimaguas, and then recrossed the Andes to Trujillo on the coast. The story of their adventures stirs the imagination and although they collected only plants their observations on animal life make the book of interest also to the zoologist, and excite his jealousy.

The book is thoroughly indexed and documented.

The Technique of Theory Construction. *International Encyclopedia of Unified Science, Volume II, Number 5.*

By J. H. Woodger. University of Chicago Press, Chicago. $1.00. 9½ x 6¾; vii + 81; 1939 (paper).

A detailed and elementary account of the application of the method of modern symbolic logic to the construction of theories in general, with particular reference to biological theories. The development of the technique is so clear and simplified that this brochure may well serve as the starting point for anyone wishing to learn the elementary operations in this field.

There appears to be a minor slip on p. 13, where the following passage occurs:

"Thus, of the following four examples of substitution in '*p* implies *q*', the first three are true statements and the fourth alone is false:
(1) (2 + 2 = 4) implies (Rome is in Italy)
(2) (2 + 2 = 5) implies (Rome is in Italy)
(3) (2 + 2 = 5) implies (Rome is in France)
(4) (2 + 2 = 4) implies (Rome is in France)"

Surely if (1) and (3) are "true statements", as in the author's sense they obviously are, then by the same token (2) cannot be a "true statement" because 2 + 2 *does not* equal 5, but Rome *is* in fact in Italy.

Veröffentlichungen des Deutsch-Dominikanischen Tropenforschungsinstituts. *Hamburg—Ciudad Trujillo D.S.D. Band I.*

Edited by Adolf Meyer-Abich. Gustav Fischer, Jena. 10 x 6¾; 143 + 20 plates; 1939 (paper).

This is the inaugural number of collected publications from the German-Dominican Institute for Tropical Research which was organized in the summer of 1937. The

first paper, by Adolf Meyer-Abich, contains a history of the Institute, a description of the buildings, the aims and scope of work. The other articles include: a description of *Cichlasoma vombergi*, nov. spec., by W. Ladiges; amphibians and reptiles from Santo Domingo, described by R. Mertens; anatomical reactions of the digestive tract of the parrot, *Amazona ventralis*, by M. Grasmann; two articles on microscopic fungi of the Dominican Republic, by R. Harder and G. Sörgel; geology of the Cordillera Central of Santo Domingo, by R. Weyl; and the spread of malaria in the province of Barahona, by F. Marschall.

TRANSACTIONS OF THE SAN DIEGO SOCIETY OF NATURAL HISTORY. *Vol. 9, Nos. 14a and 15. A New Subspecies of the Western Worm Snake*, by Laurence M. Klauber; *Two New Pocket Gophers from the Desert Slope of Eastern San Diego County, California*, by Laurence M. Huey.

Society of Natural History, San Diego, Calif. 10½ x 6⅞; No. 14a, 2; No. 15, 4 + 2 plates; 1939 (paper).

HUMAN BIOLOGY

BLACK FOLK, THEN AND NOW. *An Essay in the History and Sociology of the Negro Race.*

By W. E. Burghardt Du Bois. Henry Holt and Co., New York. $3.50. 9¼ x 6⅛; ix + 401; 1939.

Here is a straightforward attempt by an educated colored man to tell the story of his race. To those who ask why such a story should be told, the answer is "Because it has never been told before." We all know that the Negro was imported to America and other so-called civilized regions to supply the demand for slave labor, and we know something of the vicissitudes through which the race has passed, particularly in our own southern states. But the innocent reader whose knowledge of African history is confined to Diaz and Vasco de Gower and Livingstone and du Chaillu and the Martin Johnsons is due for a shock when he learns that for nearly a thousand years before any of these worthies the dark continent had been permeated by Islam, and that from Islamic sources can be read the authentic accounts of nations and dynasties that rose and fell, of war and famine and the migration of peoples essentially similar to the kind of events that have occurred in every other continent.

While Du Bois is not averse to the term "Negro" he prefers to call his people "Black Folk". Although "Negro" is merely the Spanish word for black, it is a term that has been used in many diverse senses by ethnologists, and he believes that less confusion will result from the use of the English transliteration. He interprets his race in the broad sense, including all the dark-skinned, kinky-haired people such as the Dravidians and Berbers, without regard to dolicocephaly or physiognomy. To do otherwise would be to restrict the Negro to a group so small that it could not reasonably be designated a race.

Du Bois believes that the human species originated in Africa and was dark skinned. Every dark skin today is the persistence of a primitive trait. One difficulty with this theory is that the broad nose and everted lips commonly associated with the Negro race can hardly be considered primitive, as they do not occur in any pithecoid stock, which seem to have more features in common with Caucasoid physiognomy. If primitive *Homo* was black, he must have been more like the black of the Indo-Pacific region than those of Africa.

It is now commonly believed that the ancient Egyptians had black skins. References to this fact in classical literature are too numerous not to be convincing. Du Bois believes them to have been mulattoes between barbarian Semites from Arabia and civilized Ethopians from the head waters of the Nile, and he derives a rather convincing argument from Ethiopian history which goes back nearly as far as that of Egypt.

There are some errors in the book. For instance, the author tells us that after Estebanico was killed by the Indians it was over forty years before another effort was made to penetrate New Mexico.

As a matter of fact it was less than two years after the arrival at Compostela of Cabeza de Vaca, Estebanico's white companion, that Coronado, Alvarado, El Tovar, and de Nizo had penetrated not only New Mexico but Arizona, Colorado, Oklahoma, and Kansas. Also Du Bois has misquoted Wendell Phillips' eulogy of Toussaint l'Ouverture by omitting the reference to John Brown.

The author makes an excellent point, after noting that more than fifty million Black Folk were sold into slavery in less than three centuries, by enquiring what would have been the state of white civilization today if an equivalent proportion of able-bodied whites had been impressed into slavery in Africa. But in the natural resentment which he feels against those who perpetrated the infamous traffic in human beings he overlooks the fact that the first dealer in slaves in America was a Negro apprentice who learned from his own bitter experience what pecuniary profit might accrue from the sale of his less fortunate brethren to the avaricious whites.

A better index and a few more maps would have increased the value of this excellent book.

AGRICULTURE IN MODERN LIFE.
By O. E. Baker, Ralph Borsodi, and M. L. Wilson. Harper and Brothers, New York and London. $3.50. 9¼ x 5⅞; vii + 303; 1939.

In this volume Ralph Borsodi, founder of the Suffern School of Living, O. E. Baker, the distinguished agricultural economist, and M. L. Wilson, Under Secretary of Agriculture, incisively present the case for more self-sufficient living. The book originated in a 1938 conference at Northwestern University on "Distributive Society and the Possibilities of Decentralization."

These authors agree that agriculture is more than "soil mining", it is a "way of life". Baker, by elaborate economic statistics; Borsodi, by broad social reasoning; and Wilson, by reference to sociological ideas and facts; present a rural culture where bare sustenance levels are often scarcely maintained, and this where 20 per cent of our people live, where 35 per cent of our capital is invested, and where 50 per cent of our citizens are born. The intimate relationship between this rural problem and the urban problem of unemployment and relief is clearly shown.

The authors, agreeing that most of the profits of specialized farming are consumed in higher distribution costs, advocate more self-sufficient farming, not on the Robinson Crusoe level, but by using all the facilities of a scientific and industrial age to assist in achieving a better way of living.

The final section of the book, a dialogue among the authors, shows their fundamental agreement on the principles involved, but emphasizes that all specific efforts to apply these principles are still in the experimental stage. Altogether this is a significant contribution.

CRITIQUES OF RESEARCH IN THE SOCIAL SCIENCES: *I. An Appraisal of Thomas and Znaniecki's The Polish Peasant in Europe and America. Bulletin 44.*
By Herbert Blumer. Statements by William I. Thomas and Florian Znaniecki, a panel discussion, and summary and analysis by Read Bain. Social Science Research Council, 230 Park Ave., New York. $1.00. 9 x 6; xvii + 210; 1939 (paper).

The Social Science Research Council has set out to appraise the outstanding studies which have influenced sociology during the last two decades or more. The purpose apparently is to determine whether such studies might lead to "the development of a self-contained and self-recruiting cult perpetuating inquiries and reports of no substantial social value, either in promise for the future or relevance for the present." A number of books have been chosen to be evaluated and among them the review of *The Polish Peasant in Europe and America*, by Thomas and Znaniecki, is the first to be completed and thus represents the first of the series to be published. This report contains Professor Blumer's review, statements by the authors of the book and also, what seems to be, a stenographic account of the panel

discussion by members of the Social Science Research Council. Blumer's review of *The Polish Peasant* is painstaking and thorough and his main criticism is levelled at the fallacies that might result from the authors' interpretations of the letters which formed the basic material of the book. The authors, in turn, justify their methodology and further explain their viewpoint which emphasizes the subjective individual element in social relations. The panel discussion, as is usual, makes for amusing reading. For reasons not easily understood, Blumer rather than *The Polish Peasant* was subjected to a verbal assault which was of the "define your terms and what is truth" kind. In addition, almost every member present took the occasion to air his views about matters not directly concerned with the subject under discussion. It is to be hoped that the other publications of the series, especially if they contain reviews as well written as this by Blumer, will not also be used as a vehicle for outbursts of professorial pronouncements.

TANGIER ISLAND. *A Study of an Isolated Group.*

By S. Warren Hall, III. University of Pennsylvania Press, Philadelphia; Oxford University Press, London. $1.50. 9 x 6; x + 122 + 2 plates; 1939.

This is an interesting sociological study of an isolated community on an island in Chesapeake Bay. Although politically Tangier is part of Virginia, it is geographically and culturally a part of the peninsula between Chesapeake and Delaware Bays. The speech of its inhabitants is entirely free of the characteristic inflection so wide-spread south of the Potomac, partly because their ancestors settled here in the early days before the southerners had acquired their distinctive intonation, and partly because so many of them came from New England.

During the two wars that have decimated Virginia soil no army ever invaded the Delmarva peninsula—in fact, it is doubtful whether any resident of Tangier ever undertook military service. Slavery was never introduced. The culture of the past has been preserved into the present only slightly altered by the passage of time.

The leading spirit among these early settlers was a rugged and vigorous pioneer named Joshua Thomas, around whose memory tradition has so accumulated that he has become a semi-mythical patriarch whose dead hand to a large extent still moulds Tangier culture today. And a good culture it is, in some ways in advance of that on the mainland. It reaches its culmination in a system of socialized medicine, by which each family pays the resident physician a monthly salary receiving in return the medical service it requires without further expenditure.

More recently time and the tides of the Chesapeake have taken their toll of that part of the island formerly available for residential and agricultural purposes with the natural result that the dwindling population is becoming more and more dependent on the mainland. Its distinctive culture is being forced unwillingly into conformity and will eventually disappear. The present investigation is timely and was made none too soon.

ARCHAEOLOGY AND SOCIETY.

By Grahame Clark. Methuen and Co., London. 7s. 6d. net. 7¼ x 5¾; xv + 220 + 24 plates; 1939.

This book, which is primarily concerned with prehistoric rather than historic archaeology, is designed for the use of the general reader. Although the author has attempted to write in a simple style using as little as possible of the superabundant terminology already encumbering the young science of prehistoric archaeology, nevertheless the general reader who tackles this book will be confronted with a sizable amount of esoteric nomenclature. The definition of prehistoric archaeology and the history of its study are discussed. Then the following subjects are considered in order: (1) how ancient sites are found and the factors instrumental in their discovery; (2) what factors regulate the preservation of early remains; (3) the modes of excavation, and the difficulties incurred therein; (4) the relative and

absolute dating of findings; and (5) the interpretation of the findings in terms of the people of the past and their societies with the interrelations of such aspects as food supply, living area, form of settlements and houses, material culture, art and religion, density of population, and social organization and behavior. Numerous concrete examples of archaeological work are presented and findings described that range over a great portion of the globe. Lastly, the author discusses archaeology and its present use in spreading propaganda, especially in such countries as Italy, Germany, and Russia. He also considers briefly the falsity of the "superior" people conception in the light of the study of prehistoric archaeology. There are many interesting sketches and diagrams and splendid full-page photographs.

THOREAU: REPORTER OF THE UNIVERSE. *A Selection of His Writings about Nature, for all Readers from Eight Years Old to Eighty.*

Selected and Arranged by Bertha Stevens. The John Day Co., New York. $2.50. 8 x 5½; xiv + 229 + 8 plates + 1 folding map; 1939.

It is only a few of us who can have the privilege of meeting nature on such intimate terms as Thoreau. The cumber and entanglements of modern civilization are too much with us. But when we take up such a book as this and read of the sounds, colors, and smells of forest and field, and their seasonal fluctuation, or of the stories recorded in the animal tracks in the snow, of the snow crystals that sting his face, or the spears of the much maligned skunk cabbage that herald the coming of spring by perforating the snow banks that remain in sheltered places, or the voice of the stream liberated from its icy prison, or later, the voice of the toad recently waking from its hibernation as it trills its joy at the renascence of life, or the solemn crash of a patriarch of the forest as it falls to its death, we can ask ourselves; Why have we allowed ourselves to become slaves to our environment when we might have been its masters?

The woodpeckers still percuss the hollow trunks, the sap still drops from the red maple, and the beach grass still traces circles in the sand, but there is no Thoreau to observe and record these things. Our minds are too occupied in making present wars and preparing for future ones. But at least we can find time to read Thoreau. The fourteen volumes of his collected works are here condensed into one, the material arranged topically. The only adequate expression of the value of such a book that a reviewer can make is to advise all his readers to get it and share it with him.

INDIANS OF THE AMERICAS. *Historical Pageant.*

By Edwin R. Embree. Houghton Mifflin Co., Boston. $2.75. 8½ x 5¾; xi + 260; 1939.

An American history "written not around the colonists and immigrants but around the native Americans." The probable course of the Indian peoples as they entered this continent by way of Bering Straits and spread fan-like throughout the Western Hemisphere, in successive waves of migrations during pre-historic times, is pictured. These people, of a single stock — Mongoloid — lived together in groups for hundreds or thousands of years, "cut off almost completely from people of other customs. Each group built its life on the basis of the habits it had brought with it and on the environment of its new home." This lack of contact with other types of culture and of ideas kept the Indian civilization more or less stabilized at a low level. It was only in those regions where contact among the various tribes was greatest that cultural development reached its highest level, namely among the Aztecs in Mexico, the Mayas in Central America and the Incas in Peru. Separate sections are devoted to these three groups—their art, learning, religion and history.

The latter half of the book is concerned with the different tribes of the North American Indian; and the final pages,

with the new governmental policy for the present day Indian. The volume contains many interesting illustrations and is well documented and indexed.

THE CHINESE ARE LIKE THAT.

By Carl Crow. Harper and Brothers, New York and London. $3.00. 8⅝ x 5¾; viii + 328; 1939.

It is apparent from this book that in the twenty odd years the author spent as an advertising man in China, he has gained a shrewd insight into Chinese character and custom, a genuine fondness for these people, and a high regard for the many ways in which they have met the struggle for survival and live uncomplainingly in the midst of flood and famine, poverty, scarcity of firewood and pure water, and over-population. Here he shows how rice (in the south) and noodles (in the north), which do not require a long and steady fire for cooking, came to be the staple diets of the country, not because of what "Confucius say", but because of deforestation resulting in scarcity of firewood and game. He shows the extent of the famine that would result if modern plumbing were installed in every home to replace the present custom, found nauseating by foreigners visiting the country, of collecting human manure for disposal over the fields. He traces the origin of another custom found annoying to foreigners, namely that of "squeeze", which incidentally seems to be a trait of servants all over the world. He writes of beggars, bandits, noise, superstitions and many other things. Most of the attitudes of mind and customs which non-Chinese find peculiar, Crow finds can be logically traced back to some basic reason. Written in a popular style and illustrated with amusing anecdotes this book is nevertheless worth the perusal of the serious minded student of human populations and customs. It has been published in England under the title *My Friends, the Chinese.*

RACIAL PROVERBS. *A Selection of the World's Proverbs Arranged Linguistically. With Authoritative Introductions to the Proverbs of 27 Countries and Races.*

By Selwyn G. Champion. The Macmillan Co., New York. $10.00. 9½ x 6; cxxix + 767; 1939.

Proverbs are important to the human biologist. They are the quintessential distillates from the long boiling of the great pot of human experience. When a Chinese boy's grandfather suggests to him that: "If you bow, bow low", he is imparting to him a bit of wordly wisdom based upon a vast experience of human behavior. Obeisance, toadying, bootlicking, or whatever it is called, may or may not be an advisable action in a particular situation; but if it is decided to be the sound thing to do in the premises, racial experience has demonstrated that a thorough job had best be done.

From the point of view of the student of human behavior, as well as from every other conceivable, except perhaps the narrowly philological, this huge collection of proverbs assembled on a racial (national) basis will be a boon to students. Twenty-seven distinguished scholars contribute introductions to as many sections, starting with an African section for which R. R. Marett is responsible, and an Arabic section from the pen of Prof. H. A. R. Gibb; and ending with the Turkish (S. Topalian) and the Welsh (J. J. Jones). There is a 20-page bibliography of authorities consulted; and three detailed indices.

Altogether this collection of 26,000 odd proverbs from 186 languages and dialects, that cost the editor 27 years of research, is a scholarly contribution of a high order of importance.

SOCIAL RESEARCH.

By Manuel C. Elmer. Prentice-Hall, Inc., New York. $3.00. 8 x 5½; xvi + 522; 1939.

The purpose of this book is to outline the principles and philosophy of research in the social sciences. As the author notes, the methods of research so well established in other branches of science have not been utilized to any great extent in sociology. One of the reasons, he believes, is that "social research has fre-

quently manifested itself as a vehicle for changing the social order rather than of understanding the social order." This is only too true, although not many professional sociologists are willing to admit it. There are three research techniques that the author describes in this book: (1) the general historical method of studying events and institutions, (2) the individual life history, (3) the case method. The last mentioned is discussed in great detail with particular reference to its use in so-called surveys. For all methodological approaches, in general, the author refers at length to the problems involved in sampling, the choice of adequate control groups, the use of statistical analysis and the various scales employed in measuring individual and social group attributes and phenomena. Although to students trained in biology and biometrics the book may seem very elementary, it is worth reading for the good choice of illustrative examples and adequate bibliography.

HORSES AND AMERICANS.

By Phil Stong. End paper and chapter heads by Kurt Wiese. Frederick A. Stokes Co., New York. $5.00. 10¼ x 7½; xx + 333 + 65 plates; 1939.

Here we have a book decidedly easy to read, in which has been accumulated a most amazing quantity of information about the horse and its development in America.

No horses were native to the continent when Columbus made his voyages but they arrived here almost on the rudder of the *Santa Maria*, certainly within ten years of the navigator's death. Velasquez established the animals in Cuba, one of Columbus' first discoveries, in 1511; seven years later the island furnished mounts for the conquest of Mexico.

The author brings us into close contact with the different breeds of horses, which we are familiar with in a general way, and explains their usefulness as decided by their build—saddle and race horses, hunters, cow ponies, heavy Percherons, Clydesdales, Belgians, Morgans, and just horses, some pure bred and some crossed. Stong also makes us aware of the exceedingly important part played by the horse during the settlement of this country, and speculates as to how much the development and extension of our territory might have been retarded without them. Many illustrations are included, a substantial bibliography, and an index.

ANTHROPOLOGY AND RELIGION.

By Peter H. Buck. Yale University Press, New Haven; Oxford University Press, London. $1.50. 8 x 5½; viii + 96 + 1 folding chart; 1939.

This book embodies the sixteenth series of Terry Lectures on Religion in the Light of Science and Philosophy, delivered at Yale University. Professor Buck, who was born in New Zealand of a Maori mother, traces the history of Polynesian religion, its development and solidification, and eventual destruction with the advent of Christianity. The Polynesians deified certain of their ancestors and thus created their gods, the priesthood developed and fixed the theology and, as the author says, the man-created gods in turn re-made man. The culture and whole civilization of the Polynesians became centered around their religion. Then came the Christian missionaries with a new set of morals and a new theology and by their well-known persuasive methods converted the natives. As a consequence the whole fabric of the Polynesian civilization came apart. In closing, the author points to the importance of Christianity in the development of western civilization and warns of the possible downfall of this civilization if Christianity should be abandoned. An interesting and well-written book.

THE CULTURE HISTORICAL METHOD OF ETHNOLOGY. *The Scientific Approach to the Racial Question.*

By Wilhelm Schmidt. Translated by S. A. Sieber. Fortuny's, New York. $5.00. 9 x 6; xxx + 383; 1939.

The primary purpose of this tedious, dull, and badly written treatise, appears to have been to bring about a wider dissemination of the ideas and theories of

Graebner and Schmidt about what they hold to be the true methodological gospel of ethnology. Particularly there was apparently a hope that by translating Graebner's *Methode* and spreading it about in chunks through a diluent it might be made readable. It is our duty to report that the hope was largely illusory. As the result of a prolonged, careful, and sympathetic study of this volume it is our conviction: (a) that Boas was profoundly right and wise in refusing to accept the *Kulturkreis* theory of Frobenius, Graebner, Schmidt and Co., because "it is based on the assumption of the permanence of correlations of supposedly identical cultural traits, the identity of which has not been safely established and which in modern cultures prove to be unstable"; and (b) that if the company wants to promote the sale of its eyewash it will do well to employ a bright young man who can write clearly and logically so to put the product out in a brighter, cleaner, and generally more attractive package.

OUT OF REVOLUTION. *Autobiography of Western Man.*

By Eugen Rosenstock-Huessy. William Morrow and Co., New York. $6.00. 8¾ x 5¾; xii + 795; 1939.

Out of Revolution, an autobiography of western man, is a philosophy of history with "revolution" as its arbitrary unit of progress. The author attempts to show the human experiences and thoughts underlying revolutions and the interdependence of revolutions to each other. The author treats history as the autobiography of man and the revolutions that have made history and have given "man's soul a new relation between present, past and future" as having their foundations in the alternating passions of humankind.

In the first part of the book the author discusses the great revolutions of Russia, France, England, and Germany, a four-hundred-year span of history; in the second part, the clerical revolutions in Italy and the American Revolution. The author quite often sacrifices clarity of meaning to a well-turned sentence or phrase and drowns the meaning of his analyses in a flood of unnecessary verbosity. The volume is well illustrated, and has a detailed index. An explanatory list of maps and illustrations is appended to the text.

RELIGION IN PRIMITIVE SOCIETY.

By Wilson D. Wallis. F. S. Crofts and Co., New York. $5.00. 9 x 6; ix + 388 + 8 plates; 1939.

Wallis presents a thorough and scholarly review of the ritualistic manifestations of religion and of the concept of sacredness in various religions. In order, he describes the several kinds of sacred places, objects, trees, animals and persons. He then discusses the rituals of consecration, purification, sacrifice and feasts. The book ends with chapters on the beliefs about life after death. Although, as the title indicates, the author is concerned with the religion of pre-literate cultures he discusses equally the manifestations of Hindu, Mohammedan, Roman, Greek and Jewish (thereby also the Christian) religions. The great value of this work lies in the fact that it is devoted to a description rather than to an interpretation of the overt practices of religion. For this reason and because it contains an extensive bibliography this book will without doubt become a standard source of reference on the subject.

UNDER YOUR FEET. *The Story of the American Mound Builders.*

By Blanche Busey King. Dodd, Mead and Co., New York. $2.50. 8½ x 5¾; xii + 169 + 25 plates; 1939.

The story of the moundbuilder and his place in American pre-history has never been adequately told. Although the valleys of the Ohio and Mississippi are full of his works, many of which have been excavated, the knowledge about his culture is in a widely scattered state; it has never been coordinated, or even collated.

In this book an active archaeologist with a curiously diffuse literary style has

attempted to supply this deficiency. Although largely a recital of personal experience and crowded with reminiscences that have nothing to do with archaeology, it is a readable work that covers the ground thoroughly and gives an accurate account of the mysterious progenitors of the modern Indian. The illustrations are good, the documentation weak, and there is no index.

ANTHROPOLOGIA CRIMINAL (*Conferencias e Communicações*).

By Leonidio Ribeiro. Imprensa Nacional, Rio de Janeiro. 10¾ x 7½; xii + 97 + 27 plates; 1937 (paper).

This volume contains a collection of papers presented and read by the author at several Portuguese universities and at the 1937 Paris Congress on Legal Medicine and Industrial Hygiene. The articles concern three subjects: juvenile delinquency, homosexuality, and the effects of leprosy on fingerprints. The papers regarding the first two subjects contain mainly summary reviews of theories. The author is an adherent of the neo-Lombrosian school of criminologists and believes that delinquency as well as homosexuality represent manifestations of biological variations and consequently are medical more than police problems. Of particular interest are the observations presented relative to the changes in the fingerprints as a result of leprosy. Apparently this disease brings about the one exception to the fixity of fingerprints and creates a problem relative to police identification. In turn, the author notes, this alteration may be of value in the study of the course of the disease.

MY LIFE. *Autobiography of Havelock Ellis. Houghton Mifflin Co., Boston.* $3.75. 8¼ x 5⅝; xii + 647 + 8 plates; 1939.

Havelock Ellis, stating his belief that "of all forms of prose, there is no form so precious in its nature and so permanent in its value as an autobiography", defines the purpose of *My Life* as the "desire that my experience of life may help those who come after me to live their own lives". The work emphasizes the "inner man" and is chiefly noteworthy for the impassioned correspondence with his wife.

The book was "an act of prolonged precision in cold blood, beyond anything else that I have written" and was completed only shortly before his death. The style is detached, calm, rambling and reminiscent, enlivened only by the correspondence.

The noble plan of showing that "this is life" achieves more of ashes and dust than of living. Of itself, the book, though beautifully written, arouses no intensity of interest. Any permanent value that the autobiography may possess lies in the fact that it serves as a documentation of the actually far more interesting life and times of its famous author.

FAMILY INCOME AND EXPENDITURES: *Plains and Mountain Region. Part One, Family Income. U. S. Department of Agriculture. Miscellaneous Publication No. 345. Consumer Purchases Study. Urban and Village Series.*

By Gertrude S. Weiss, Day Monroe and Kathryn Cronister. Government Printing Office, Washington. 30 cents. 9⅛ x 5¾; iv + 330; 1939 (paper).

This investigation was carried on from January 1935 to December 1936, in several small cities and villages in the Plains and Mountain Regions of the west, and covers the pooled income of native-born families consisting of husband and wife, children, and others living with them. The income, both earned and unearned, is broken down and studied statistically from many angles. The numerous tables recorded should be of value to students of socio-economics. They may also be useful and enlightening in the study of population—all this provided the results indicated by the different tables can be relied upon as to the information upon which they are based. One gets the impression that some of the data used might not be reliable. This seems to apply principally to the report on income of the different groups. There does not seem

to be any method of checking statements made as to income.

THE EYAK INDIANS OF THE COPPER RIVER DELTA, ALASKA.

By Kaj Birket-Smith and Frederica de Laguna. University of Pennsylvania Press, Philadelphia; Levin and Munksgaard, Copenhagen. $6.00. 9½ x 6; 592 + 17 plates + 1 folding chart; 1938 (paper).

This long and somewhat rambling ethnological account of the Eyak Indians is based upon material gathered by the authors during an archaeological and ethnological expedition to Prince William Sound during the summer of 1933.

In the first part of the report the authors discuss in detail the various phases of Eyak material, their social and intellectual culture. Part II, devoted to native folk lore, consists largely of a series of stories and legends which the authors have repeated as nearly as possible in the language of their native informants. Some of these are quite delightful in their simplicity. Part III is a critical analysis of the previous work on the Eyak, and Part IV attempts to analyse the various forms of Eyak culture discussed in Part I.

Appendices include a genealogical table and over 25 pages of Eyak vocabulary. Some excellent photographs, maps and a few text figures supplement the work. There is also an extensive bibliography.

PEOPLE. *The Quantity and Quality of Population.*

By Henry Pratt Fairchild. Henry Holt and Co., New York. $3.00. 8⅛ x 5½; [6] + 315 + 8 plates; 1939.

This is a discussion of the quantitative and qualitative aspects of population with the mathematics omitted. Specialists who enjoy reading vital statistics can obtain them from other sources, but the object of this work is to stimulate interest in population problems among those who have had no special preparation for quantitative work.

The doctrine of Malthus is discussed with great clarity, and is interpreted in a somewhat different form from its popular conception. The problems attending birth control and the qualitative aspect of population, i.e., eugenics, are discussed lucidly. The index is very analytic and covers 15 pages.

RURAL MIGRATION IN THE UNITED STATES. *Works Progress Administration, Division of Research. Research Monograph XIX.*

By C. E. Lively and Conrad Taeuber. U. S. Government Printing Office, Washington. 9¾ x 6¾; xxi + 192 + 12 plates; 1939 (paper).

As a basis for the WPA programs of unemployment relief and guided migration, the movements of rural population have been studied both before and since 1930. The analysis is based on census data, and on data gathered directly from 22,000 rural families in field surveys. Widespread economic need in rural areas is made clearly evident.

ZOÖLOGY

CELLULOID SAFARI. *Filming Big Game from Cape to Cairo.*

By Stirling Gillespie. Photographs by J. Blake Dalrymple and the Author. Blackie and Son, London and Glasgow. 20s. 6d. net. 8½ x 5½; x + 278 + 63 plates + 1 map; 1939.

This is the record of the experiences of two young Scotsmen who traveled from Capetown to Cairo in "Big Bertha", a Ford V8 sedan, covered more than 25,000 miles mainly along the eastern coast of Africa, and arrived in Cairo three days sooner than the 455-day allotted schedule. The purpose of the expedition was to photograph and film educational material on the native life and wild animal life of Africa for the use of British and Empire Schools. The book is written in a highly entertaining conversational style, and no one who reads it will be able to suppress laughter over the difficulties incurred by the young men in getting "Big Bertha"

to Cairo. Very interesting to photographers will be the descriptions of the stalking of big prey with cameras. "It was strange that we had come through Africa without a rifle or shot-gun. . . . But at no time were we tempted to destroy the creatures we were photographing, nor did we find it necessary to kill in self-defense, except in the case of two deadly snakes." There are many amusing anecdotes about the natives, especially about the Zulus who cast aside all things native as contemptible. These natives had donned such European clothing as moth-eaten football jerseys, tams, berets, felt hats, while some, preferring to exhibit their entire wardrobes, would wear as many as three greatcoats on the most sweltering days. This book gives an excellent picture of the population of Africa, both white and native, its wild life, and the topography of the land with emphasis laid on the traveling conditions on man-made routes and off the beaten tracks. There are numerous full-page photographs. On the front end-paper there is a map showing the route taken by the two photographers.

MY FRIENDS THE BABOONS.
By Eugène N. Marais. Methuen and Co., London. 5s. net. 7¾ x 5½; vii + 124; 1939.

The author believes that

> If mankind wishes to escape the doom which now threatens its existence on earth; if, in the last ditch, man still wishes to fight unrelenting nature, it would appear possible only by the adoption of one strategical measure and that is the variation from type and the great increase in population must be stopped in some scientific way. For this purpose science must be called in, and the first step towards acquiring the necessary knowledge to arm man for his last struggle for existence is a thorough study of the animal species most nearly related to man—the apes and anthropoid apes.

This account of the activities of a colony of baboons of South Africa is interesting, but not entirely convincing. We doubt that mankind will be saved by a study of this nature. The entire account of the behavior of these apes is tinged with the author's anthropomorphic conception of how they should behave, and as a consequence one becomes skeptical. This is unfortunate, for there is much material gathered here for the first time on the social life of baboons in their wild and natural state.

In one of the chapters the author expounds the theory "that birth-pain is the key that awakens the psychological impetus of mother-love." "In the baboon mother-love reaches a higher stage of development than in any other animal in our country and the birth-pain she suffers is proportionate to it."

WILD ANIMALS. *Great Wild Animal Stories of Our Day.*
Compiled by Frances E. Clarke. The Macmillan Co., New York. $2.50. 8¼ x 5¾; x + 335; 1939.

The charm of this collection lies not only in its beautifully written stories and essays (25 in number), but also in the well-selected diversity of its subject matter and appeal. For the reader who desires an essay on the spiritual side of nature and the conservation of its wild life and plant beauty, there is the article "Thou Shalt Not Kill", by James Oliver Curwood who died before this, his last article, could be put into type; for the reader who likes a story of nature with a dash of Tolstoi-like religious moral at the conclusion, there is "The Truce of God," by Laurence Housman. For one who likes a good animal story with action, but no sentimentality, there is the story, "The Black Coyote," by Myron M. Stearns; for one who likes an animal story with a tinge of sentimental tragedy, there is the story of the giant ape mother "The Prisoner," by Madelon Lulofs. For the reader who likes his story with a dash of comedy there is the story of Ulysses Skunk entitled "The Lord of the Trail", by Kenneth Gilbert. Muztagh, the great white Indian elephant; Alessandro, the little hurdy-gurdy monkey who returned to the jungle to dance before his jungle relatives in a green pea-jacket; Joe Dokes, the African-born circus lion who was a beloved retired veteran of the Grand Amalgamated Circus; and Koala, the little Australian marsupial

bear, are some animal-heroes, about whom not-to-be-forgotten stories have been written, that have been included in this excellent anthology.

AMERICAN MAMMALS: *Their Lives, Habits, and Economic Relations.*

By W. J. Hamilton, Jr. McGraw-Hill Book Company, New York and London. $3.75. 9 x 6; xii + 434; 1939.

Mammalogists, naturalists, sportsmen, and biologists will rejoice to hear that there is finally available an up-to-date book on the biology of mammals. Previous works have heretofore been limited in scope, usually being either taxonomic, distributional, or economic, with scattered notes on behavior and life history. Hamilton presents a general and broad review of the lives, habits, and economic relations of American mammals.

The book properly starts out with the ancestry and classification of the mammals, followed by chapters on their general biology which include their adaptations, food, reproduction, homes, hibernation and migration, populations, behavior, and distribution. The final chapters are devoted to the economic importance of these animals, their usefulness and destructiveness, and their value as fur and game.

THE WAY OF A LION.

By Alden G. Stevens. Drawings by George F. Mason. Frederick A. Stokes Co., New York. $1.75. $8\frac{5}{8}$ x $5\frac{3}{4}$; xvi + 144; 1939.

The Way of a Lion represents the best in animal stories. It is a far cry from the usual sentimentalized fiction. This is not the life history of an imaginary lion, but one which the author himself has seen and about which he has heard much from the Masai warriors of East Africa. The hero, a great giant of a lion with a massive head, is not only picturesque but full of cunning. His prowess as a hunter had spread the length and breadth of the Serengetti. The author, however, does not just present the lion as a mighty monarch of the jungle. The reader is told of the lion's birth (ca. 1920) in a cave on a hill somewhere north of Ngoro Ngoro, his awkward cubhood, his orphaned, lonely life as a cub in the bush, his youth and mating, his supremacy as a lord of the plains, encounters with men and animals, and finally, death met courageously and in the prime of life. Here is a story that is realistic, but not sentimentalized; vivid, but not sensational. The story has a rich setting—the plains and forests of East Africa with the intensely hot sun of the "blue, blue sky of Africa" blazing down upon all. There are seven full-page drawings and numerous marginal sketches. A fascinating record of animal life for adults and children from 12 on.

DESTRUCTIVE AND USEFUL INSECTS: *Their Habits and Control. Second Edition.*

By C. L. Metcalf and W. P. Flint. McGraw-Hill Book Company, New York and London. $7.50. 9 x 6; xvi + 981; 1939.

The great advances in the science of insects, especially in the field of economic entomology has made a complete revision of the first edition (Q. R. B., Vol. 4, p. 436) of this book necessary. The methods of insect control with insecticides of arsenic and lead have been replaced, life histories have been worked out, and the bionomics, morphology, and physiology of insects have progressed to such an extent that nearly every page of this huge text has been altered.

An interesting new feature is a key to the orders of insects in their immature stages in addition to the usual key to the adults. The first part of the book is devoted to the morphology, development, and classification of insects, followed by chapters on insect control. From this point on the insects are described according to the host plant or animal. The insect's importance, the type of injury it incurs, the plants attacked, its distribution, life history, appearance, and habits are all part of the information given for each species. Following the discussion are one or more references to more detailed works.

This excellent textbook is profusely illustrated and well indexed.

STANFORD ICHTHYOLOGICAL BULLETIN. Volume I, Numbers 1, 2, 3, and 4.

Edited by George S. Meyers. Natural History Museum, Stanford University, California. In exchange for journal or serial containing material of ichthyological or fisheries interest. 10 x 6¾; 160; Nos. 1 and 2, 1938, Nos. 3 and 4, 1939 (paper).

This new Bulletin, which will be issued irregularly depending on the material at hand, is introduced as a vehicle for the publication of the results of ichthyological research originating in, or connected with, the Natural History Museum of Stanford University. Systematic revisions, phylogenetic studies, and correlations of scattered works in classification will be given precedence over mere lists or reports on collections.

The present numbers are concerned with the following subjects: West Indian clupeid fishes of the genus *Harengula;* Two new gobiid fishes of the genus *Gobiosoma* from Lower California; Contributions toward a revision of the ophichthyid eels. I. The genera *Callechelys* and *Bascanichthys*, with descriptions of new species and notes on *Myrichthys*; A review of the myctophid fishes of the Pacific coast of the United States and of Lower California.

THE CARE OF A SMALL RAT COLONY.

By Rolland J. Main. C. V. Mosby Co., St. Louis. $2.00. 8½ x 5¾; 101; 1939.

Careful planning is as necessary for the successful colonization of rats as it is for any other group of the animal kingdom that is to be subjected to experimentation. The present treatise is a report of the "experience rather than a discussion of the entire field" in the establishment of a small rat colony at the Medical College of Virginia, and includes "that information of which we were in dire need when starting the colony." Existing publications gave some valuable information (a list of 15 titles is given in the appendix, which also contains a list of firms where cages and equipment, and feeds can be obtained), but mostly it was by the method of "trying and rejecting various procedures" that the satisfactory methods herein described concerning equipment, hygiene, rearing, feeding, and many phases of daily routine were obtained. Included in the text are illustrations of apparatus and charts. A number of amusing rat caricatures, drawn by Dr. Margaret Pennington, are used as chapter tailpieces. An excellent index is provided.

THE BUTTERFLIES OF THE NIAGARA FRONTIER REGION *and Beginner's Guide for Collecting, Rearing and Preserving Them. Bulletin of the Buffalo Society of Natural Sciences, Volume XIX, Number 1.*

By William Wild. Buffalo Museum of Science Press, Buffalo, N. Y. $1.00. 9¾ x 6¼; 55; 1939 (paper).

The list of eight families of butterflies native to the Niagara frontier region will be of interest to only a limited number of naturalists working in that region. However, the monograph contains much that will be of interest to everyone everywhere whose studies concern the Lepidoptera. The discussions on the life history of butterflies in general, the methods of collecting, rearing, and preserving butterflies and moths will appeal to the latter group.

In the matter of classification, the author has followed McDunnough's Check List of 1938.

The 12 figures, the 8 plates carrying 88 illustrations, the bibliography of 11 titles, and the complete and well-arranged index serve the volume well in its intended purpose as a field guide and reference book.

A LABORATORY GUIDE IN ENTOMOLOGY: *For Introductory Courses.*

By Robert Matheson. Comstock Publishing Co., Ithaca, N. Y. $2.00. 11 x 7¾; vii + 135; 1939.

This well-planned and carefully-prepared

manual is intended for use in the laboratory work connected with an introductory course in entomology. The nature of the work is such that a fundamental knowledge of invertebrate zoology is prerequisite for undertaking it. The material is organized around the taxonomic and general biological aspects of entomology. The first nine studies are devoted to the external structure and metamorphosis of a typical insect. There follows, in studies X to XXI, a series of discussions on the characteristics used in classifying the principal families of ten orders of our common insects. Studies XXII to XXVIII deal with the behavior and economic importance of several groups of insects, particularly insect pests.

An appendix dealing with methods of collecting, preparing, mounting, preserving and rearing insects, and an informative glossary serve to round out this comprehensive and authoritative laboratory manual.

CANADIAN LAND BIRDS. *A Pocket Field Guide.*

By P. A. Taverner. Illustrated by Allan Brooks, F. C. Hennessey and P. A. Taverner. David McKay Co., Philadelphia. $2.50. 6½ x 4⅛; 277; 1939.

This colorful field guide of Canadian birds will undoubtedly acquire immediate popularity among professional as well as amateur ornithologists.

The early chapters deal briefly with the following subjects: (1) methods of bird study; (2) methods of attracting birds to our gardens; (3) plans for building bird houses; and (4) the topography of the characteristic land bird. There follows a comprehensive field color key, and finally a listing of some thirty-eight families of familiar Canadian birds, together with brief notes on the size, field marks, voice, habitat, nest and eggs of each group. The scientific nomenclature follows the check list of the American Ornithologists' Union (1931) edition. The carefully drawn and beautifully colored plates greatly enhance the value of the volume as a pocket guide.

FIELDBOOK OF ILLINOIS LAND SNAILS. *Manual 2.*

By Frank C. Baker. Natural History Survey Division, Urbana, Ill. $1.00. 7⅛ x 4½; xi + 166; 1939.

This is a perfect example of what a field book should be. The brief introduction contains an account of the anatomy of a land snail, instructions for collecting shells and displaying them in a cabinet, and descriptions of the physiography and geology of Illinois. The systematic portion of the book is exhaustive, covering all snails known to have been taken in the state, whether native or exotic. Of each one there is an excellent drawing. Snails whose presence is doubtful are listed without illustration, but with a bibliographic reference in an appendix.

There is a topical index of six pages and a systematic index of one, yet the book can be comfortably carried in the coat pocket. A field book of this sort will be welcomed by every field malacologist.

AN INTRODUCTION TO ANIMAL BIOLOGY.

By John B. Parker and John J. Clarke. C. V. Mosby Co., St. Louis. $3.75. 8½ x 5½; 503; 1939.

Taking Agassiz' advice to "Study Nature, not books," the authors intend their book to be used in conjunction with a laboratory course covering essentially the same material. With a few exceptions each chapter could be used as the basis of a laboratory exercise, yet there is a sufficient amount of theoretical material included to make a well-rounded text. The authors, who are on the staff of the Catholic University of America, have been particularly careful in their handling of topics that touch on religious faith and morality—for example, the paragraphs on evolution and the statements on venereal disease. There are many illustrations.

SEPIA. *L.M.B.C. Memoirs on Typical British Marine Plants and Animals. Edited by R. J. Daniel, XXXII.*

By David H. Tompsett. University Press

of Liverpool, Liverpool. 12s. 6d. net. 9½ x 6; vii + 184 + 24 plates; 1939.

This is a very thorough anatomical study of one of the more plentiful species of Cephalopods in European waters. It is of course highly technical and of no special interest except to the systematist. The most striking anatomical feature of this squid is the hectocotylus, which is never detached, but is used by the male to transfer the spermatozoa from its own mantle cavity to the bursa copulatrix of the female. There is nothing in the treatise about the cleavage of the egg, or any embryological processes, and naturally, nothing about the probable evolution of Cephalopods from the primitive molluscan type, though this latter is figured and briefly described. The 24 plates are beautifully prepared.

THE TRAMPLING HERD. *The Story of the Cattle Range in America.*

By Paul I. Wellman. Illustrated by F. Miller. Carrick and Evans, New York. $3.00. 8½ x 5⅝; 433; 1939.

In 1521 an enterprising Spaniard brought 6 or 7 calves to Mexico. They thrived and multiplied, and the business of raising cattle flourished beyond the Rio Grande. The "trampling herd" gradually displaced the buffalo from the prairies to the north; and by the middle of the 19th century they grazed on open range as far as the Canadian border, and from the Mississippi to the Rockies. The brief era of the traditional "old west", of Billy-the-Kid, Wild Bill Hickok, and Wyatt Earp, of recorded "trail-drives", booming cow towns, and gun fights, marked the disappearance of the open range. Mr. Wellman's story of the transition from free land to fenced fields reveals the changing balance between a rapidly growing population and its natural resources. It is an interesting book, as readable as the author's novel of cowboy life, *Jubal Troop.*

THE GEESE FLY HIGH.

By Florence P. Jaques. Illustrated by Francis L. Jaques. University of Minnesota Press, Minneapolis. $3.00. 10½ x 7½; [6] + 103; 1939.

The Rainey Wild Life Sanctuary, now owned by the Audubon Society, is the principal setting of this book. Mrs. Jaques vividly describes how she and her husband followed the ducks and geese in their southward migration, and observed them from the Louisiana marshlands. The volume contains little of biological interest, but is rather devoted to details of the charms and chafes of the rugged existence led by the vacationers. Otherwise it is a series of excellent action pictures done in black and white by Mr. Jaques, and colored in the words of his companion.

FOOD HABITS OF PRAIRIE DOGS. *U. S. Department of Agriculture. Circular No. 529. By Leon H. Kelso. Government Printing Office, Washington.* 5 cents. 9⅛ x 6; 14; 1939 (paper).

This short bulletin presents the results of laboratory analyses of the stomachs of some 545 North American prairie dogs. About 97.47 percent of the diet of the three species examined was made up of vegetation; 78.32 percent being represented by plants important for forage or crop value, and about 19.15 percent by those unimportant for these purposes. The animal matter (2.53 percent) eaten by these forms consisted mostly of cutworms, grasshoppers and ground beetles.

A list of 11 bibliographic references is present.

FIELD GUIDE TO LOWER AQUARIUM ANIMALS.

By Edward T. Boardman. Cranbrook Institute of Science, Bulletin No. 16. Bloomfield Hills, Mich. $1.00 (paper); $1.50 (cloth). 9 x 6; 186; 1939.

This bulletin was designed primarily "as an easy reference for amateur naturalists and nature counsellors who wish to know what lower animals can be kept in home aquaria." Fishermen will also find this book full of useful information concerning fish food and fish bait. The text

concerns itself mostly with the habitats and habits of these animals, and the illustrations aid their identification. There is a selected bibliography and a glossary.

THE EXTERNAL ANATOMY OF THE LARVA OF THE PACIFIC COAST WIREWORM. *U. S. Department of Agriculture. Technical Bulletin No. 693.*

By H. P. Lanchester. Government Printing Office, Washington. 10 cents. $9\frac{1}{8}$ x $5\frac{7}{8}$; 40; 1939.

This study forms part of a general program of investigation directed toward the economic control of wireworms in the Pacific Northwest. It is preliminary to comparative studies of the several species of wireworms found in that general section. The later studies will be primarily taxonomic, but based on this morphological study. The descriptions are accompanied by line drawings and the work concludes with a bibliography of 22 titles.

ANIMALIUM CAVERNARUM CATALOGUS. *Pars 12, 13, 14.*

By B. Wolf. W. Junk, The Hague and 's-Gravenhage. Single copy Dutch Fl. 10.60; subscription price Dutch Fl. 8. $10\frac{1}{4}$ x $7\frac{1}{4}$; 298; 1937–38 (paper).

These numbers of a thorough catalogue of cavern fauna throughout the world contain authors from NOR to SCH, a list of the caves of Jugoslavia, a supplement containing data on phyla found during and after the preparation of the previous parts, and the index for Volumes I to III. Previous parts have been noticed in Vol. 10, p. 104 and Vol. 11, p. 103 of this *Review*.

UNIVERSITY OF CALIFORNIA PUBLICATIONS IN ZOOLOGY. *Vol. 43, Nos. 11, 12, 13. Organogenesis in the Gasteropod Crepidula adunca Sowerby*, by C. E. Moritz; *The Development of the Heart in the Rat*, by Paul L. Burlingame and J. A. Long; *The Early Embryology of Triturus torosus*, by J. Frank Daniel and Evangeline A. Yarwood.

University of California Press. 50 cents each. $10\frac{1}{4}$ x $6\frac{3}{4}$; No. 11, 32; No. 12, 72; No. 13, 36 + 8 plates; 1939 (paper).

BOTANY

THE BRITISH ISLANDS AND THEIR VEGETATION.

By A. G. Tansley. The Macmillan Co., New York; The University Press, Cambridge. $16.00. 10 x $6\frac{3}{4}$; xxxviii + 930 + 162 plates; 1939.

This book is intended to replace *Types of British Vegetation*—published in 1911, and out of print for the last 20 years. Tansley writes in the preface:

> The knowledge of our natural and semi-natural plant communities is much wider and especially much deeper than it was in 1911. On the other hand, various problems that we then envisaged as relatively simple have shown themselves upon further study to be very complex indeed and not yet susceptible of satisfactory solution. Thus the writing of this book has been a very different task from the writing of *Types*. In 1911 we wrote practically all we knew and a good deal that we guessed; and though many of our guesses were not far from the truth others have not unnaturally turned out to be wide of the mark.

Although the book has been constructed on the compilation plan it is far more than a compilation, as the reader quickly perceives. The author's very wide knowledge of ecology and extensive experience in appraising available information on British plant communities have enabled him to present a comprehensive treatise which will long serve as a guide for the investigator and student. The 43 chapters (with references) are arranged under the following main headings: The British Islands as environment of vegetation; History and existing distribution of vegetation; The nature and classification of vegetation; The woodlands; The grasslands; The Hydroseres: Freshwater, marsh, fen and bog vegetation; Heath and moor; Mountain vegetation; Maritime and submarine vegetation. The numerous illustrations and excellent working index help to make this a standard reference work of the first rank of importance—one that should be made available to all students of ecological problems.

I CEREALI DELL'AFRICA ITALIANA. *I. I frumenti dell'Africa Orientale Italiana studiati su materiali originali.*

By Raffaele Ciferri and Guido R. Giglioli. Preface by A. Maugini. Regio Istituto Agronomico per l'Africa Italiana, Firenze. 40 Lire. $9\frac{5}{8}$ x $6\frac{3}{4}$; ix + 298 + 1 folding chart; 1939 (paper).

After the conquest of Ethiopia, the Italian government has directed its major efforts to the development of the agricultural production of the country so that it would at least satisfy the local needs and, hopefully, increase the food supply of Italy. Extensive and intensive research in agriculture and the allied branches of science have therefore been greatly encouraged and among others a large scale investigation on grain cereals has been systematically organized. The initial step in this investigation has been a survey of the cereals that have been acclimated in Ethiopia and this monograph is the first of a series of reports on the observations. It is concerned with the taxonomic classification of the species and varieties of *Triticum* found. Altogether 293 varieties are described in full and illustrated. Of this number 97 varieties belong to *T. turgidum abyss.*, 92 to *T. durum abyss.*, 60 to *T. vulgare* (*ligulatum*) and the remaining belong to *T. dicoccum*, *T. pyramidale*, *T. polonicum* and *T. compactum*. Specimens of other kinds of *Triticum* not heretofore described have also been uncovered but whether they represent stable varieties or simply hybrids will have to be decided by genetic experimentation. The geographic distribution of the species and varieties as well as their frequency are also described. It is a thorough and important contribution to the subject and one which brings to date, extends and also clarifies the observations of Koernicke, Chiovenda, Percival and Vavilov.

EARTH'S GREEN MANTLE. *Plant Science for the General Reader.*

By Sydney Mangham. Foreword by Sir Arthur W. Hill. The Macmillan Co., New York. $3.50. $8\frac{5}{8}$ x $5\frac{5}{8}$; 322 + 40 plates; 1939.

In this popularly written account of plant life the author discusses with scientific accuracy the various aspects of plants and their relation to the environment. He attempts to give a realization of the true significance of the plant in human affairs. With the aid of photographic and other illustrations, he outlines the story of man's continuous efforts to understand and utilize the wealth of plant life; of the parts played by other branches of science in the development of plant knowledge; and of the use made, and perhaps yet to be made, of such knowledge. He tells something of the history of the use of plants; of the early explorations and discoveries when the search was for spices from the orient, of the sixteenth century immigration of the potato from South America to Europe; and of the Dutch use of marram grass to stabilize sand dunes and cord grass to reclaim shallow lands from the ocean.

An appendix contains suggestions for further reading, and there is a long and complete index.

MAGIC GARDENS. *A Modern Chronicle of Herbs and Savory Seeds.*

By Rosetta E. Clarkson. Illustrated from the Old Herbals and Ancient Gardening Books. The Macmillan Co., New York. $3.00. $8\frac{1}{2}$ x $5\frac{3}{4}$; xviii + 369; 1939.

Magic Gardens has been, perhaps unconsciously, in the making for many years. The author, an ardent herb cultivator at Salt Acres, her place in Connecticut, and editor of the *Herb Journal*, is an assiduous collector of literature on the subject—much of which goes back to very early times. Herein she writes enthusiastically and entertainingly of the 16th century "knotted" gardens of England, the "parterres" of France, the mazes and labyrinths of early Roman and Egyptian times. Detailed descriptions of something over 200 plants are given and their uses in medicine, cooking, potpourris and sachets.

"From undated times herbs of the field have played an almost unbelievably prominent part, not only in the life of the individual in his own home, but in the existence of civilized nations. . . . Today, any fragrant flower or leaf is almost certainly a descendant of an old-time herb."

The volume is illustrated by reproductions from old herbals and prints and concludes with indexes of books and authors, of herbs, and of subject matter.

BOOK OF THE BROADLEAF TREES. *The Story and the Economic, Social, and Cultural Contribution of the Temperate Broad-Leaved Trees and Forests of the World.*

By Frank H. Lamb. W. W. Norton and Co., New York. $3.75. 8½ x 5⅝; 367 + 41 plates; 1939.

Anyone who has ever stood under some famous elm or oak and tried to visualize the historic scenes that occurred within sight of its ancient trunk, or anyone who has entered a forest and felt thrilled and somewhat awed at the majestic dignity of its trees will renew these pleasures by reading this book. It is not a scientific treatise on trees, but an account of their history, romance, uses, beauty. The author has travelled widely and his first-hand experience enables him to speak authoritatively. He is acquainted with the Australian eucalyptus and African baobab, as well as with the birches of our North and the live oaks of the South. All those having any interest in broad leaf trees, whether from an economic, scientific, or historic standpoint, will not only find this book interesting but informative. It is well illustrated.

PROPAGATION OF HORTICULTURAL PLANTS.

By Guy W. Adriance and Fred. R. Brison. McGraw-Hill Book Co., New York and London. $3.00. 9 x 6; ix + 314; 1939.

An excellent text for students in horticulture.

The essential features of plant structure and reproduction have been introduced in their relation to seed production, root formation, wound healing, and other practical phases of plant propagation. The methods of asexual propagation, including bulbs, layerage, cuttage, budding, and grafting are considered in comprehensive form.

Included also are detailed discussions of the propogation of certain important species, such as the peach, plum, apricot, cherry, almond, apple, grape, etc. Sections are devoted to plant diseases, transplanting, and the growing and handling of nursery stock. The volume is well documented and illustrated and has an adequate index.

INTRODUCTION TO FLORAL MECHANISM.

By S. G. Jones. Chemical Publishing Co., New York. $4.00. 8½ x 5⅝; xi + 274; 1939.

This book, for students in technical colleges and first-year university students, gives a new approach to the study of flowering plants. Emphasis is put on the flower as the *mechanism of inheritance* and the structure, development and functions of flowers are studied from this point of view. Recent developments in cytology and genetics are applied to heredity, hybridization and plant breeding. The latter part of the book (Part II) discusses the keying of a plant to its taxonomic group. This part systematically treats 21 selected families of monocotyledons and dicotyledons. The 70 original, full-page illustrations are finely done and add much to the value of the text. There is a small glossary of terms. The index is well done but the bibliography is brief and not entirely adequate.

EDIBLE WILD PLANTS.

By Oliver P. Medsger. With an introduction by Ernest T. Seton. The Macmillan Co., New York. $3.50. 8 x 5; xv + 323 + 16 plates; 1939.

In this comprehensive and useful handbook the author describes in detail 69 species of edible fruits and berries, 33 of salad plants and potherbs, 9 of roots and tubers, 11 of sugars and gums, 15 of nuts, 20 of beverage and flavoring plants, 15 of seed and seed pods, and lists many more with brief descriptions. In addition to the regular index and in the place of a key, the author has included an excellent "finding index" which gives the names of plants, both common and scientific, with the range, season, and a few of the most pronounced characteristics. The volume is well illustrated with pen and ink drawings and photographs. There is, however, no bibliography.

LABORATORY MANUAL FOR GENERAL BACTERIOLOGY. *Second Edition.*

Compiled by George L. Peltier, Carl E. Georgi and Lawrence F. Lindgren. John Wiley and Sons, New York; Chapman and Hall, London. $2.00. 10¾ x 8½; viii + 279; 1939.

This manual, a second edition of a 1938 publication, is concise and comprehensive. There are 57 exercises in all, but the authors intend that the instructor shall make his own selection to suit the particular needs of his class. In this way the manual can be used for classes primarily interested in agriculture, home economics, or sanitary engineering, or for general or pre-medical groups. Descriptive charts, formulae for stains and media, and a bibliography are included.

AN ILLUSTRATED MANUAL OF CALIFORNIA SHRUBS.

By Howard E. McMinn. With a chapter on The Use of the California Shrubs in the Garden Design, by Fred H. Schumacher. J. W. Stacey, Inc., San Francisco. $5.00. 9¼ x 6; xi + 689; 1939.

North of Tehachapi there are more flowering plants than in any other state, and south of them there are more than twice as many. Probably never before has a work covering all of them been undertaken—certainly no more comprehensive work is conceivable. There are 775 illustrations, a glossary, an index, a dictionary of taxonomic terms, and a bibliography, together covering 32 pages, also additional chapters on the ecology of wild plants and their use in the garden. All told, this is a complete work of reference, and every resident of the coast who owns his home should have a copy.

CHEMICAL INVESTIGATIONS OF THE RHUBARB PLANT.

By Hubert B. Vickery, George W. Pucher, Alfred J. Wakeman and Charles S. Leavenworth. Connecticut Agricultural Experiment Station, New Haven. Bulletin 424. 25 cents. 9 x 6; 157; 1939 (paper).

Parts I and II of this Bulletin give the details of separate experiments carried out with rhubarb leaves collected in two successive years from the same farm. The results of the analyses of these leaves, cultured in darkness and in light, are discussed in terms of chemical mechanisms that have been proposed to explain the reactions that may take place in leaf tissues. An interpretation of the data in terms of modern views of plant metabolism has been attempted in Part III. The text is supplemented by numerous tables and there is a complete index.

VEGETABLE CROPS. *Third Edition.*

By Homer C. Thompson. McGraw-Hill Book Co., New York and London. $5.00. 9 x 6; xi + 578; 1939.

In this edition have been incorporated all the important advances which have been made in the application of scientific facts and principles to the successful production of vegetables and the successful handling of the products since the second edition was issued in 1930. This has frequently involved much revision, especially in such subjects as fertilizer practices, soil reaction, the use of minor or trace elements to control malnutrition troubles, the control of diseases and insects and the packaging, handling, and storage of vegetables.

SUPPLEMENT TO ROOT NODULE BACTERIA AND LEGUMINOUS PLANTS.

By Edwin B. Fred, Ira L. Baldwin and Elizabeth McCoy. University of Wisconsin Press, Madison. 50 cents. 10¼ x 6¾; 40; 1939 (paper).

To supplement the bibliography of 1073 titles in the original volume of *Root Nodule Bacteria and Leguminous Plants* (Q. R. B., Vol. VIII, p. 228) the authors have compiled a new list of: (a) 49 titles omitted in the monograph; and (b) 482 titles of new literature. The supplement also cites 39 errata in the original monograph, and presents two additional indices; one to scientific plant names, and the other to author citations.

ORCHIDS OF MICHIGAN.

By Marjorie T. Bingham. Cranbrook Institute of Science, Bloomfield Hills, Mich. Bulletin No. 15. $1.00 (paper); $1.50 (bound). 9 x 6; 87 + 22 plates; 1939.

The fifty-three different kinds of orchids found in Michigan are described in this bulletin in non-technical language for the lay naturalist. A key to the species follows some introductory notes on their culture, distribution, and conservation. There are many illustrations of these rare plants, some of which are in water color.

KEYS TO THE PHYLA OF ORGANISMS: *Including Keys to the Orders of the Plant Kingdom.*

By Fred A. Barkley. Associated Student's Store, Missoula, Montana. 75 cents. 8 x 10¾; [4] + 39; 1939 (paper).

A useful outline, particularly for courses in plant morphology. The keys were assembled from various sources but especially from the writings of C. E. Bessey and J. H. Schaffner. The contents are divided as follows: A synoptic key to the phyla of organisms, keys to the orders of the various plant phyla, outline of the classification used, glossary, and references.

TEN YEAR PROGRESS REPORT 1928–1938. *Black Rock Forest Bulletin No. 10.*

By Henry H. Tryon. With an Introduction by C. F. Korstian. Black Rock Forest, Cornwall-on-Hudson, New York. $1.50. 9 x 5¾; iv + 76; 1939 (paper).

THE NITROGEN NUTRITION AND GROWTH OF CERTAIN DECIDUOUS TREES OF NORTHEASTERN UNITED STATES. *With a Discussion of the Principles and Practice of Leaf Analysis as Applied to Forest Trees. Black Rock Forest Bulletin No. 11.*

By Harold L. Mitchell and Robert F. Chandler, Jr. Black Rock Forest, Cornwall-on-Hudson, New York. $2.00. 9 x 5¾; vii + 94; 1939 (paper).

A HIGH-DUTY WOODSAW. *Black Rock Forest Papers, Vol. 1, No. 15.*

By Henry H. Tryon. Black Rock Forest, Cornwall-on-Hudson, New York. 11 x 8½; 100–102; 1939 (paper).

MORPHOLOGY

THE RISE OF EMBRYOLOGY.

By Arthur W. Meyer. Stanford University Press, Stanford University, Calif.; Oxford University Press, London. $6.00. 9 x 6; xv + 367 + 58 plates; 1939.

Possibly no other branch of biology has had its history so well presented in our day as embryology; certainly no other branch has a written history which so interestingly displays the errant ways of man in his pursuit of knowledge. In evidence, the latest contribution of Arthur William Meyer may be offered. It aims to trace the growth of embryological ideas, beginning with the ideas on generation held by primitive peoples, and progressing through the ideas of scholars, both early and late, in order to try to discover "why our intellectual ancestors should have been led to entertain views which strike us as absurd" [the words were Huxley's].

If to review past error is one way to avoid future absurdity, this book should be required reading for science students. So, too, the *Quarterly Review of Biology* asserted on the occasion of an earlier publication of Meyer. For students of preformation and epigenesis, the present work is indispensable.

A LABORATORY MANUAL OF VERTEBRATE EMBRYOLOGY. *Anatomy of Selected Embryos of the Frog, Chick, and Pig.*

By F. B. Adamstone and Waldo Shumway. John Wiley and Sons, New York; Chapman and Hall, London. $1.25. 11 x 8¾; vii + 87; 1939 (paper).

The interpretation of serial sections is always difficult for the beginning student of microscopical anatomy; and the difficulty is not overcome by drawing a few individual and supposedly representative sections. This new manual outlines a more promising method, as used at the University of Illinois. There the student of vertebrate embryology is required to make only informal sketches in the marginal spaces provided in his laboratory manual, but he is required to study all of the sections in any given series, to identify the structures in them, and to learn to

recognize them by means of their diagnostic features and their relation to each other.

ANATOMY OF THE SHEEP'S BRAIN. *A Laboratory Atlas for Students of Zoology.*
By E. A. Briggs. Angus and Robertson, Sydney. 6s. net. 8¾ x 5¾; xiii + 50 + 8 plates; 1939.

This brief text and the accompanying illustrations are designed primarily for students pursuing a junior course of practical zoology. The structures described can all be observed with the unaided eye, and the statements have been so formulated as to guide the dissector in making his own observations. No attempt has been made to provide the student with a comprehensive account of all the structural details which he will encounter in a complete dissection of his specimen. The descriptive matter is intended to serve as an introduction to the study of the principal points of interest in the mammalian brain. The book contains a detailed index and also a group of eight excellently-drawn and well-labeled plates which greatly enhance the value of the text as a laboratory manual.

THE ANATOMY OF THE BULL FROG.
By Richard R. Stuart. Denoyer-Geppert Co., Chicago. 50 cents. 11 x 8½; 30; 1939 (paper).

These thirty-three original drawings made by the author from his dissections of the bull frog, *Rana catesbiana*, should be of excellent visual aid to the beginner in the study of frog anatomy. The drawings are good-sized and simply labeled. As all directions and descriptions are omitted the drawings should be used with at least one descriptive text. The manual is divided into three sections of drawings—skeletal, muscular, and internal. There is a name index.

GUIDE TO THE STUDY OF THE ANATOMY OF THE SHARK, THE NECTURUS, AND THE CAT.
By Samuel Eddy, Clarence P. Oliver and John P. Turner. John Wiley and Sons, New York; Chapman and Hall, London. $1.50. 9 x 6; vii + 100; 1939 (paper).

This manual is designed primarily for the course in comparative vertebrate anatomy given at the University of Minnesota, where the type forms are dissected in succession. Because of time limitations, less detailed studies are made on some organ-systems than on others, the muscular and skeletal systems being especially abbreviated.

PHYSIOLOGY AND PATHOLOGY

HEALTH IN HANDCUFFS.
By John A. Kingsbury. Modern Age Books, New York. 75 cents. 7¾ x 5½; ix + 210; 1939 (paper).

This is a very well written and comprehensive piece of propagandizing on behalf of socialized health insurance. This is not to be confused with socialized medicine. The latter implies universal free medical service supported by general taxation, and seems just as radical a departure for today as our present socialized public school system did when first initiated.

But there is nothing very radical about insurance against impairment of health, or rather the loss caused by it. We can already insure against loss by a multitude of other calamities—flood, fire, lightning, theft, etc., and can purchase disability benefits from many life insurance companies.

In many parts of this country the hospitals are so far apart and the resident physicians so few that insurance providing for hospitalization and medical care has no practical value. To remedy this the Wagner National Health Bill (S. 1620) has been introduced into the Senate. This would provide for government establishment of hospitals where needed and their maintenance, so that their advantages would be readily available to all at a reasonable charge. Opposition to this bill has come chiefly from the American Medical Association—the group who would probably benefit most from its passage, for under it the income of the

physician would be guaranteed, competition would be eliminated, as well as the necessity for the physician to feel the patient's purse as well as his pulse before diagnosing his case and prescribing treatment.

THE PRINCIPLES OF INSECT PHYSIOLOGY. *By V. B. Wigglesworth. E. P. Dutton and Co., New York.* $8.00. 9¾ x 6⅝; viii + 434; 1939.

This new treatise on insect physiology is an outgrowth of the author's small volume entitled *Insect Physiology*, published in 1934. Insects have been intensively studied, and numerous books have appeared on their economic importance, life histories, taxonomy, and recently their morphology. All the experimental research on their physiology, however, has been published in scattered journals, and while much work has been done in this field, no one has ever synthesized the results.

There are in all twelve chapters dealing with the integument, growth, the various organ systems, metabolism, water, and temperature. After each chapter there is an extensive bibliography, so that altogether over 2000 titles are cited. The fact that insects are so varied in kinds and habits makes it necessary to define which creature it is that a particular statement applies to; consequently the text is heavily loaded with generic names.

This book is of great importance to biologists generally. Research workers using insects as subjects of experimentation will attain more precise methods with a sound background in insect physiology. It will also fill a great want for economic entomologists, who in attempting insect control need a knowledge of their physiology in order to strike at the phase in the life cycle that is most vulnerable.

A generous number of illustrations and an index add to the value of this important contribution to zoology.

HORMONES IN INVERTEBRATES. *By Bertil Hanström. Oxford University Press, New York; The Clarendon Press, Oxford.* $4.25. 8¾ x 5½; ix + 198 + 13 plates; 1939.

As recently as 1933 the existence of definite endocrine substances and endocrine producing organs in invertebrates was denied by many investigators. In this excellent treatise Hanström has presented a most convincing account not only of the existence of hormones in invertebrates, but also of the specific effects of a number of them on both vertebrates and invertebrates, as well as the effects of various vertebrate hormones on invertebrate organisms. Koller's classification of invertebrate hormones, i.e., (1) 'Zellhormone', (2) 'aglanduläre Gewebshormone', and (3) 'glanduläre Gewebshormone', is considered by the author to be logical and useful in discussing the problem, and the subject matter of the volume has been developed along these three lines. The range of material includes the recent work on the hormones influencing sex, reproduction, metamorphosis, and color change in a wide variety of invertebrate organisms.

The text is carefully organized and well written in clear English. Numerous illustrations pertinent to the subject have been included. The indices of (1) authors, (2) scientific names, and (3) general subject matter, as well as the list of 860 bibliographic references add considerably to the value of this volume as a reference book.

THE VASOMOTOR SYSTEM IN ANOXIA AND ASPHYXIA. *A Study of the Adjustment Reactions of the Mammalian Organism. By Ernst Gellhorn and Edward H. Lambert. University of Illinois Press, Urbana.* $1.00 (paper); $1.50 (cloth). 11 x 8; 71; 1939.

This study deals with the effect of various gas mixtures (1 to 10 percent oxygen and 4 to 15 percent CO_2) on the blood pressure of dogs anaesthetized with sodium amytal, sodium barbital, or chloralosane. Among the significant results are the following:

Under conditions in which carbon dioxide and oxygen deficiency cause a rise in blood pressure, i.e., in the normal dog with and without artificial respiration, and further after vagotomy *or* removal of both carotid sinus areas with artificial respiration, the effect of carbon dioxide plus low oxygen tension is

greater than corresponds to the algebraic sum of the individual effects.

In the dog deprived completely of its buffer nerves and artificially ventilated, it is found that carbon dioxide completely offsets the fall of blood pressure produced by the inhalation of a gas with a low oxygen tension.

The experiments indicate that the cause of this potentiation lies in the fact that the effect of carbon dioxide is increased in anoxia. This is in part due to the weakening of the carotid sinus pressor reflexes. In addition to that it is assumed that the intracellular metabolites formed during short periods of anoxia may interact with the effects of carbon dioxide and thereby cause the potentiating effect described above.

There is a bibliography of 152 titles.

THE STATISTICS OF PULMONARY TUBERCULOSIS IN DENMARK 1925–1934. *A statistical investigation on the occurrence of pulmonary tuberculosis in the period 1925–1934, worked out on the basis of the Danish National Health Service file of notified cases and of deaths.*

By Marie Lindhardt. Ejnar Munksgaard, Copenhagen. Kr. 8. 10½ x 7; 179 + 1 folding table; 1939 (paper).

The present investigation was undertaken on the basis of the file of consumptives kept by the Danish National Health Service. These tuberculosis notifications, which since 1920 have been regularly treated statistically, have been collected under a rational filing system since 1925. The present investigation comprises 39,379 notifications of new cases received by the National Health Service between 1925 and 1934, and 20,173 notifications of deaths occurring in the same period. In this report the distribution of tuberculosis in various parts of the country according to age, sex, civil status, etc., and its nature, duration, lethality, seasonal fluctuations, and incidence within various groups are thoroughly discussed and illustrated with numerous graphs and tables. Supplementary tables are included in the appendix, and there is an extensive bibliography.

THE VITAMINS. *A Symposium Arranged Under the Auspices of the Council on Pharmacy and Chemistry and the Council on Foods of the American Medical Association.*

American Medical Association, Chicago. $1.50. 8¼ x 5½; 637; 1939.

VITAMIN D. *Chemistry, Physiology, Pharmacology, Pathology, Experimental and Clinical Investigations.*

By C. I. Reed, H. C. Struck and I. E. Steck. University of Chicago Press, Chicago. $4.50. 9 x 6; xviii + 389; 1939.

A good summary of a field of work, and a detailed report on any part of that field are always of value. These two books are admirable examples. The vitamin symposium, arranged under the auspices of the American Medical Association, numbered 30 authorities among its participants; it presents a digest of what is known about each vitamin. This book gives the reader a fairly comprehensive idea of the importance of vitamin therapy in modern medicine.

The second book is a résumé of what is known about Vitamin D, and a working report from a laboratory active in its study. Scientists, teachers, industrialists, druggists, and physicians will find this a dependable reference. Both books are careful to make it clear that the field of vitamin study is far from being worked-out, and that there is much to be done before what is known can be applied to best advantage.

DIE FUNKTION DER NEBENNIERENRINDE. *By F. Verzár. Benno Schwabe and Co., Basel.* 25 Swiss francs. 8¾ x 6; 266; 1939.

In this attractively printed volume the professor of physiology in the University of Basel presents a comprehensively thorough, critical review and synthesis of the literature on the function of the adrenal cortex, in which the results of his own important work in this field are clearly set forth and brought into their proper place in the general picture. It is now certain that cortin, the hormone of the adrenal cortex, is a substance of fundamental importance in the metabolism of the cell generally. Lack of this hormone starts a train of changes in fat metabolism, and in carbohydrate formation in the cell that lead finally to failure of heat regulation, of selective glucose resorption, of glycogen formation in the liver, of K elimination

by the kidney, loss of plasma from the blood, and death.

In its logical, clear, and concise elucidation of an extremely complicated field this book is a masterpiece. The bibliography, set in the most condensed form, occupies 30 pages and covers the literature to 1939. A valuable addition to any biological library.

STUDIES IN THE PHYSIOLOGY OF THE KIDNEY. *Porter Lectures, Series IX. Delivered at the University of Kansas School of Medicine.*

By Homer W. Smith. University Extension Division, University of Kansas, Lawrence. $1.00. $8\frac{5}{8}$ x $5\frac{3}{4}$; [6] + 106; 1939.

The first lecture in this series is concerned with the physiological bases of recently developed methods for examining the normal and diseased kidney, such as functional methods of measuring the glomerular filtrations, the renal blood flow, and the quantity of intact, active glomerular and tubular tissue. In the second lecture the general evolutionary history of the vertebrates is discussed with special reference to the kidney of fishes. The final lecture on the renal blood flow in normal and hypertensive subjects, deals largely with experimental work, such as the effect on renal function of various substances (oil of juniper, adrenin, ephedrine), vasodilatation of the renal arterioles, relationship of renal arterioles and the nervous system. In this section is given a chart "summarizing the more important data in renal function as found in 15 hypertensive subjects." A number of diagrams and figures will be found in the volume, each lecture is well documented, but no index has been provided.

THE FLOWERING OF AN IDEA. *A Play Presenting the Origin and Early Development of The Johns Hopkins Hospital.*

By Alan M. Chesney. The Johns Hopkins Press, Baltimore. $1.50. $8\frac{1}{2}$ x $5\frac{1}{2}$; 87; 1939.

Written for the celebration of the fiftieth anniversary of the opening of The Johns Hopkins Hospital, the story of this play centers about the origin, early development and formal opening of the hospital. The play, in four scenes, is admirably adapted for just such a formal occasion. The first scene, wherein an imaginary conversation takes place between Johns Hopkins and George Peabody concerning the uses to which they intend to put their money, gives the author a chance to show the interesting personalities of these two men. The dialogue throughout the play seems somewhat stilted, but this stiffness of style is partly a true characteristic of the times portrayed, and partly to be attributed to the fact that, with the exception of the first scene, official records and documents were closely followed.

ZOÖLOGICA. *Scientific Contributions of the New York Zoölogical Society. Volume XXIV, Part 3, Numbers 10–26.*

New York Zoölogical Society, Zoölogical Park, New York. $2.00. $10\frac{1}{2}$ x 7; 120 + 22 plates; 1939 (paper).

This issue of *Zoölogica* reads much like a number of the *Journal of the American Medical Association* and for this reason we have put this review in "Physiology and Pathology". Of the 17 papers, 14 form the bulk of the report of the Hospital and Laboratory of the New York Zoölogical Park for 1938. The first number gives a résumé of the causes of death in the collection. As a basis for this, the International Classification of Causes of Death adopted for man by an International Committee in 1929 is used, although some modification has been necessary to exclude those diseases to which animals are immune and to include those diseases which attack only animals. Other papers deal with carcinoma of the pancreas in a bear, goiter in a dromedary, dental pathology, parasites of wild rats, *Multiceps serialis* infestation in a baboon, amoebic dysentery in an orang-utan, etc. All of the papers carry bibliographic references and many excellent photographs add to the interest of the texts.

PRINCIPLES AND PRACTICE OF AVIATION MEDICINE.

By Harry G. Armstrong. Williams & Wilkins Co., Baltimore. $6.50. 9 x 6; xii + 496; 1939.

Progress in aviation has been accompanied by the increased realization that new kinds of medical problems arise from the unusual environment in which the flier finds himself. To deal particularly with such problems a specialized branch of medicine is now in the process of being definitely formed. The author has brought together and examines in this volume most of the available literature on the several phases of the subject. The first nine chapters are concerned with the selection of pilots, the physical and psychic requirements they should possess, the standards of examination used in this and other countries. The remaining twenty-nine chapters deal with the evidence so far collected on the physiological, psychological and pathological manifestations associated with flying. Although necessarily sketchy in parts the book covers well the whole vast range of the subject and contains an excellent bibliography.

NUTRITION AND DIET IN HEALTH AND DISEASE. *Third Edition, Entirely Rewritten.*

By James S. McLester. W. B. Saunders Co., Philadelphia and London. $8.00. 9⅛ x 6; 838; 1939.

In the twelve years which have elapsed since the first appearance of this book "newer discoveries have been so far reaching and the changes in the point of view so extreme" that it has been necessary completely to rewrite this edition. Only occasional paragraphs have been retained, such as those dealing with Sippy's method of treating peptic ulcers. A relatively large amount of space has been given to the nature and physiologic influences of the several nutritive substances and to the discussions of disordered physiology.

Part I deals with nutrition in health (3 sections, 314 pages); Part II, with nutrition in disease (436 pages); Part III, appendix (*ca.* 60 pages) contains considerable tabular matter. The volume is thoroughly documented and indexed. Teachers and practicing physicians will find this a dependable guide.

LIQUOR, THE SERVANT OF MAN.

By Walton Hall Smith and Ferdinand C. Helwig. Little, Brown and Co., Boston. $2.00. 8 x 5⅜; [4] + 273; 1939.

This volume presents a sound and unbiassed review of much of the more important scientific work that has been done on the biological effects of alcohol. The style of writing will probably offend some readers, for the same kind of reason that baby-talk from aged spinsters is irritating to some people. But leaving this aside, the reader of this book, which is the product of the collaboration of a professional writer and a pathologist, will get a just picture of what is presently known about the ways and degrees in which alcohol affects physiological, psychological, and pathological processes in man. Much of it will be new, even to the biologist who has not himself actually worked in this field. The book has no index, which is a pity, because its organization lacks that kind of precision that might help in using it for reference purposes in the absence of an index.

AN INTRODUCTION TO MEDICAL MYCOLOGY.

By George M. Lewis and Mary E. Hopper. Year Book Publishers, Chicago. $5.50. 10 x 7; xviii + 315; 1939.

This text has been designed to give the student a substantial knowledge of the important phases of mycology and of the common fungus diseases. The characteristics and habits of the habitual fungus parasites are briefly but clearly described. Since the pathogenic flora varies in different parts of the world, "our emphasis on certain fungi as important in New York may not apply to the same degree in other localities." The first part deals with clinical, theoretical and experimental aspects of the subject; the second, with laboratory procedures useful in examining a

patient suspected of having one of the various mycoses. The bibliographies accompanying each section are not complete but contain "articles which we think are important for their originality and their value in teaching." There is an index.

THE JOURNAL OF ENDOCRINOLOGY. *Volume I, Number 1.*

Edited by E. C. Dodds. Oxford University Press, London and New York. Subscription price: 30s. or $6.00. 10 x 6¾; 116; 1939 (paper).

This new quarterly is founded to bring together and to make available in a single British journal papers in the English language concerning "the internally secreting glands, the mode of their actions, the nature of their secretions, and the disorders of their functions." Contributions from all countries will be welcome. Papers intended for publication should be submitted to the editors at the Courtauld Institute of Biochemistry, Middlesex Hospital, London, W. 1. The editorial board includes P. M. F. Bishop, C. R. Harington, G. F. Marrian, A. S. Parkes, F. G. Young, and S. Zuckerman.

THE ENDOCRINE GLANDS.

By Max A. Goldzieher. D. Appleton-Century Co., New York and London. $10.00. 9½ x 6½; xvi + 961; 1939.

It is the announced aim of this book to discuss systematically and thoroughly, and on the basis of first-hand information, both the theoretical and the practical aspects of endocrinology, and to abstract from the enormous literature the really important contributions which have a bearing on the practice of the clinician. Endocrinology is still a very rapidly changing field, of course. The author has not always succeeded in passing unprejudiced judgment on which contributions are clinically most important. He has succeeded single-handed, however, in marshalling a prodigious array of detailed matter in a masterly fashion. A selected bibliography follows each chapter.

HYDROPHTHALMIA OR CONGENITAL GLAUCOMA: *Its Causes, Treatment, and Outlook. By J. Ringland Anderson. With a Foreword by Sir John Herbert Parsons. The University Press, Cambridge; The Macmillan Co., New York.* $7.00. 9¾ x 6; xx + 377; 1939.

The last monograph on this subject was published in 1897. This book will therefore serve as a summary of the literature for the practicing ophthalmic surgeon. The first portion of the work deals with the pathology, morphology, and diagnosis of the disease. The remainder of the book is given over to methods of treatment and surgical techniques. Each chapter has appended a long bibliography of titles down to 1938. The tables inserted in the back cover of the book contain the data for each case discussed in the text. The work is well illustrated.

HUMAN HELMINTHOLOGY. *A Manual for Physicians, Sanitarians and Medical Zoölogists. Second Edition, Thoroughly Revised. By Ernest C. Faust. Lea and Febiger, Philadelphia.* $8.50. 9¼ x 6; 780; 1939.

This excellent and exhaustive presentation of the science of helminthology by one who for many years has been a teacher and investigator in the field first appeared ten years ago (cf. Q. R. B., Vol. 5, p. 248). In this second edition, new illustrations have been added, bringing the total to 302, and old ones have been revised and clarified. A new chapter on "Anthelmintics and Their Use" has been included, and the terminology in the book has been brought up-to-date. The extensive bibliography is placed at the end instead of being included in the individual chapters. There is both an author and subject index.

AN INTRODUCTION TO GASTRO-ENTEROLOGY. *Being the Third Edition of The Mechanics of the Digestive Tract. By Walter C. Alvarez. Paul B. Hoeber, Medical Book Department of Harper and Bros., New York and London.* $10.00. 10 x 7; xxii + 778; 1940.

This third edition of a well-known and valuable treatise is in reality a new book,

entirely rewritten and about double the size of the second edition which appeared in 1927 (cf. Q. R. B., Vol. 3, p. 450). Seven new chapters have been added and data from about 1500 new articles and books have been included. Summaries have been prepared for each chapter, and a chapter on "books and reading" lists works that will be helpful to young men who are starting their lifework in the fields encompassed by this book. The book is illustrated, and equipped with a bibliography of 114 pages and an index.

EVANS' RECENT ADVANCES IN PHYSIOLOGY. *Sixth Edition.*

Revised by W. H. Newton. The Blakiston Co., Philadelphia. $5.00. 7¾ x 5¼; xi + 490; 1939.

Much of the material in this edition has been carried over from the 5th edition (noticed in Q. R. B., Vol. 11, No. 4) and brought up to date. Several new chapters are included dealing with: (a) the physiology of bone, (b) the Carrel-Lindbergh perfusion apparatus, (c) problems of carbohydrate metabolism, (d) the cortical control of muscular movement.

HEALTH FOR NEW YORK CITY'S MILLIONS. *An Account of Activities of the Department of Health of the City of New York for 1938 with Comparative Vital Statistics Tables.*

By John L. Rice. Department of Health, City of New York, 125 Worth Street, New York. Free to libraries, schools of public health and to special organizations. 9 x 6; 295; 1939.

BIOCHEMISTRY

EXPOSÉS ANNUELS DE BIOCHIMIE MÉDICALE. *Deuxième Serie.*

Published under the Direction of Michel Polonovski. Masson et Cie, Paris. 75 francs. 9¾ x 6¾; [4] + 264; 1939 (paper).

Like the first volume of this annual (cf. Q. R. B., Volume 14, p. 376) this number includes a group of excellent papers by leading workers which should be of interest to medical practitioners and biochemists. Included are: Contributions to biological oxidation at the cellular level, by A. Szent-Györgyi; Physiological methods of the estimation of pre-deficiency states, by E. J. Bigwood; The glucides of the nerve centers, by A. Baudoin; Chemical constitution of the diastases, by M. Polonovski; Virus proteins, by Ch. Sannié; Immuno-chemistry, by M. Macheboeuf; Magnesium in biochemistry, by M. Wolff; Composition of natural phosphorus compounds and their metabolism, by P. Fleury; Cortico-suprarenal hormones, by P. Boulanger; Uric acid, by G. Florence; Rôle of nitrates in cellular metabolism, especially in the higher plants, by M. Lemoigne; and Some biochemical problems posed by ossification, by J. Roche.

BIOMETRY

PROCEEDINGS OF THE INDUSTRIAL STATISTICS CONFERENCE *held at Massachusetts Institute of Technology, Cambridge, September 8–9, 1938.*

Pitman Publishing Corp., New York and Chicago. $2.50. 9⅛ x 6⅛; [5] + 315; 1939.

This book comprises the lectures of several well-known statisticians and mathematicians on the subject of control of quality and standardization of product in industrial plants; also the application of statistical methods to research in medicine and various other fields. It is obvious that statistical control of the quality of raw materials, the behavior of machinery, etc. in large industrial plants is necessary for a more or less thorough understanding of what is taking place. It inevitably leads to better finished products, and better methods of production, which of course reduces the percentage of rejection and leads to lower cost to the consumer.

The lectures in this book explain clearly the present value and future possibilities of the use of statistics in the manufacturing world, draw attention to methods of analysis of scientific data, and also illustrate somewhat to the uninitiated the use of statistics as the safe method of proving

a fact or exploding a fallacy. A careful reading of the report may be of value in helping to solve problems along the lines indicated.

GRAPHIC PRESENTATION.

By Willard C. Brinton. Brinton Associates, New York. $5.00. 9 x 6; 512; 1939.

For many years Brinton has been the leading authority in this country on the graphic representation of statistical data. His *Graphic Methods* (1914) is the standard text on the subject. It is doubtful that the present volume will add greatly to his reputation. It is, in essence, a modernized, stream-lined, and somewhat jazzed-up re-treatment of the material, obviously influenced by present-day graphic technique in the advertising field. While every statistician will want it at hand for reference and student use, it will not wholly replace the author's earlier text. Free use of color, and great originality and ingenuity in the make-up and arrangement, make it a striking book. It is well indexed, and thoroughly documented throughout.

THE BULLETIN OF MATHEMATICAL BIOPHYSICS. *Volume 2, Number 2, June, 1940. Edited by N. Rashevsky. Editorial and Publication Offices, 5822 Drexel Avenue, Chicago.*

This number contains the following papers: The equivalence of the conduction theories of Rashevsky and Rushton, by Alvin M. Weinberg; Further contributions to the theory of cell polarity and self regulation, by N. Rashevsky; Contributions to the mathematical theory of organic form: II. Asymmetric metabolism of cellular aggregates, by N. Rashevsky; A contribution to the mathematical biophysics of psychophysical discrimination III, by H. D. Landahl; Nerve conduction theory: Some mathematical consequences of Bernstein's model, by Alvin M. Weinberg.

THE UNIVERSITY OF COLORADO STUDIES. *General Series (A), Volume 26, Number 2.* Containing the Following: *What is the Nature of Mathematics, and in what sense does Mathematics explain a Science?*, by Aubrey J. Kempner; *Abstracts of Theses and Reports for Higher Degrees, 1939.*

University of Colorado, Boulder. $1.00. 10 x 6¾; 134; 1939 (paper).

SEX

MOEURS NUPTIALS DES BÊTES.

Various Authors. Preface by Jean Rostand. Éditions Stock, Paris. 25 francs. 7½ x 5⅛; 306; 1939 (paper).

Some years ago there was mention in these columns of a contemplated treatise on *The Natural History of Copulation*, to be published in elephant folio abundantly illustrated with plates in the best tradition of zoological publication in the good old days. The present volume contributes to this worthy project by furnishing ready-made a text for the treatise, written with the sort of clarity and charming grace that French writers seem to command so much more frequently than those of other countries.

The general editor of the volume is Jean Rostand, who is probably the world's foremost popularizer of biology today, taking the whole range of pertinent values into account. Associated with him in the production of the volume are such well-known zoologists as Lucien Berland, who does the sections on the crustaceans, arachnids, and insects; L. Bertrand (fish); F. Angel (reptiles); J. Berlioz, who shares the section on birds with Jacques Delamain and Jean de Bosschère; Andrée Martignon, Jean-Émile Benech, Denyse de Stampa, G. Petit, E. Gromier, Marquis de Barthélemy, and Dr. Laurent, who between them take care of the love life of the mammals. M. Rostand, in addition to a delightful preface, does the sections on the infusoria, worms, molluscs, and batrachians.

The book is characterized by the utmost delicacy of language, but what it is all about is copulation, and nothing much else. It is extremely well done. While

intended for the general reader of the lay public, the professional biologist will find it an excellent review and digest of the main features of an interesting section of the animal behavior field.

Space is lacking to discuss particular points in any detail. The statement is made that while the preliminary courtship behavior of whales has been fairly frequently observed, their actual copulatory act has probably never been seen. A sketchy and not altogether satisfactory or convincing account is given of a single observation of the copulatory behavior of wild elephants in the wild. This has been very rarely observed; some experienced men who have devoted their lives to the study of elephant behavior say never.

The volume is well indexed and can be recommended as an addition to any biological library.

LOVE PROBLEMS OF ADOLESCENCE.
By Oliver M. Butterfield. Emerson Books, New York. $2.25. 9 x 6; viii + 212; 1939.

Some 1100 youths of both sexes ranging in age from 13 to 25 years listed, on request, the sex and matrimonial problems about which they desired information. The youths belonged to 24 separate organizations, the majority being under the auspices of Protestant churches. The inquiry shows that the questions most frequently asked regarded the propriety of juvenile heterosexual relations such as kissing and petting, while those relative to the advisability of establishing boy and girl friendships when there are differences in age and education were encountered with the least frequency. However, as can be expected due to the wide age range among the subjects, there is a considerable variation from group to group in the type of questions asked. The author discusses the results as indications of the need for more education in matters of sex relations and sex hygiene. He concludes:

> We live in an age of educational and factual abundance but we appear to suffer great privation from a poor distribution of its resources. The hope for improvement lies in attacking the situation all along the line with special stress upon the training of parents. Premarital and post-marital adult education can take up much of the lag and thus in the next generation greatly reduce the present perplexities due to ignorance.

This type of reasoning is based on the false premise which identifies theoretical with practical knowledge and culture with wisdom. Lectures and books cannot solve the immediate perplexities of a 13-year-old first adventuring into sex relations, no more than it can for one first attempting to drive an automobile or a train. Is it possible that the educators have not yet realized the implications of the methods of Montessori and of Froebel which they have accepted?

WOMEN AND MARRIAGE IN INDIA.
By P. Thomas. George Allen and Unwin, London. 7s. 6d. net. $7\frac{3}{4}$ x $5\frac{1}{4}$; 224; 1939.

With all the fire and heat of a 19th century militant suffragette the author attacks the marriage system in India and the moral theology on which it is based. To the complaisant subjection of the woman are ascribed the current ills of the country and the lack of competent leadership. Therefore, if India is to take its place in the sun the status of the woman and the prevalent form of social relationship between the sexes must be altered. The author advocates a number of reforms including the abolishment of child marriages, the establishment of the right to divorce, greater freedom of contact between the sexes, and their equality in all matters even to include the right of the wife to half of her husband's pay. Such views sound reasonable from the standpoint of our civilization and one ordinarily would be ready to cheer on the efforts to bring about such reforms. It is unfortunate, however, that this book does not evoke sympathy—due to the author's vituperative style and strange concepts of Western customs. It seems that among other objectionable qualities the Indian husbands spend a good deal of their time at home. In a characteristic manner the author assails violently such habits as the following:

Whenever the robust European woman finds her husband too home-loving or sentimental, she manages to nag him into his club or the cricket-field. But her Indian sister is too much a Pathivrita to do anything of the sort. She stands dutifully on the balcony from 5 P.M. onwards, watching her lord come home from office, tries to smile and look pleasant when he comes, proceeds to undress him, puts him to bed, presses his lean limbs and long head, feeds him out of her hand, and generally makes him the voluptuous imbecile he is. Many of the children produced in these homes are morons ending up in the street or on the banks of the Ganges.

LES HERMAPHRODITES ET LA CHIRURGIE. *By L. Ombrédanne. Masson et Cie, Paris.* 85 francs. 10 x 6½; 322; 1939 (paper).

In the case of hermaphroditism when should the surgeon intervene for corrective purposes and on the basis of what criteria should he decide to increase either the masculine or feminine appearance? These problems constitute the main theme of this volume which includes also a general survey of hermaphroditism in its embryological, morphological and physiological aspects. However, the major portion of the book is devoted to the clinical and pathological variations of persons with (a) male gonads and external feminine appearance and (b) female gonads and external masculine appearance. He considers also the question of the marriage of such persons and the views of the law and of moral theology on the subject. In great detail he describes twenty-two cases he himself observed, their personal history, the operative findings, and the reasons for the particular procedure he followed. He apparently believes that no attempt at correction should be made until puberty is passed and then surgery should usually be employed to change the form of the external genitalia so that they agree with the sex of the gonads. However, as he illustrates with his own material, there are often cases in which it is impossible or unwise to follow this rule and then the operator is legally and morally justified to change the genitalia so that they harmonize with the patient's external somatic appearance, psychic reactions and desires.

ATTAINING WOMANHOOD. *A Doctor Talks to Girls About Sex.* *By George W. Corner. Harper and Bros., New York and London.* $1.00. 7¼ x 4¾; xiii + 95; 1939.

Dr. Corner again "rings the bell" with this little volume for adolescent girls. Like its companion forerunner, *Attaining Manhood*, the facts of life are presented in simple, non-technical language, yet accuracy and clearness is maintained. This is a good example of how the simple truth, neither brutally frank nor evasive, can easily furnish an answer to that parental bugbear, the baffling question of what and how the children shall be taught about sex.

PSYCHOLOGY AND BEHAVIOR

BEYOND THE CLINICAL FRONTIERS. *A Psychiatrist Views Crowd Behavior.* *By Edward A. Strecker. W. W. Norton and Co., New York.* $2.00. 8 x 5½; 210; 1940.

There seems to be something of a trend at the present time for the clinical psychiatrist, with his experience in the intra-individual chaos presented by the psychoses and psychoneuroses, to extend his authority to the international situation with its chaos between individuals *en masse*, and to attempt to analyze the latter in terms of the former. There is a certain validity in such a critical evaluation, if not too much is said and the analogy is not drawn beyond the facts. Such an evaluation is attempted in this book, which comprises the Salmon Lectures for 1939, by Dr. Strecker, Professor of Psychiatry at the University of Pennsylvania. Outlining the similarities between the behavior of the normal individual, the mentally ill individual and the crowd or mass-man, he draws a parallel between the short-circuiting of reality by the psychotic and the mob, "Unquestionably, the world is sick—mentally sick," he states, and the temptation to ignore the checks of the intelligent minority and to utilize the escape technique of the crowd mind is becoming

stronger. In recruiting intelligent minorities who will be effective in holding the balance of power and effecting satisfactory compromises when conflicts with the primitive forces of the mass-man arise, lies Strecker's hope for civilization. This, he thinks, can be accomplished only through a broad extension of the principles and practices of mental hygiene. His observations are perspicacious and succinctly put, and the fact that they are platitudinous is perhaps inescapable. The lectures were perhaps better heard than read: this reviewer found the rather random arrangement of the material and case extracts into loose paragraphs distracting. The significance of this book would seem to be in its place as part of the trend towards an ultimate understanding of crowd behavior in terms of human personality.

War and Peace. *Essays in Psychological Analysis.*

By William Brown. A. and C. Black, London. 5s. net. 7½ x 5⅛; xvi + 93; 1939.

This book by the English psychiatrist, William Brown, was written in the spring of 1939, after the peace of Munich but before the actual outbreak of war in Europe. It is understandable that, at so critical a time as this, this philosophically-minded physician who had seen active service during the four years of the last war should feel impelled to express his views on the basis for and prevention of war. He does so in this small book of seven chapters, each a short essay emphasizing a particular feature of the central thesis that war is implicitly determined and the result of primitive aggressiveness and hostility repressed in the depths of the unconscious mind. Logically, therefore, the problem of avoiding war is to find adequate sublimation for these tendencies. This general thesis is developed by the author in a rather platitudinous and rambling fashion which does not come to any constructive point. The suggestion that all public leaders increase their self-knowledge, presumably through psychoanalysis, is made. The author affirms his faith in Prime Minister Chamberlain and in a new League of Nations. Peace, he states, will be reached "only by a deep analysis followed by a process of sublimation wherein the ideals of different nations may combine in the one ideal—a super-national ideal of free cultural and spiritual development of all human beings, whatever their nationality, each within his own national sphere and environment."

Intelligence and Crime. *A Study of Penitentiary and Reformatory Offenders.*

By Simon H. Tulchin. University of Chicago Press, Chicago. $2.00. 9 x 6; xiii + 166; 1939.

This monograph presents the results obtained from intelligence tests administered to over 10,000 inmates of 3 Illinois penal institutions during the years 1920–27. The same procedure and the same tests as those given by the army to draft recruits were employed in this study so that the data on the Illinois recruits could be used for comparative purposes. The main finding is that, on the whole and also when nativity and race (color) of the prisoner are taken into consideration, the intelligence scores of the criminals do not differ appreciably from those of the recruits. When the criminals are segregated according to type of crime committed, the highest score, on the average, was made by those who committed fraud while the score was lowest for sex criminals. This is to be expected. The author has also analyzed the data in terms of age, nativity, race (color), education, height and weight and the results are similar to the findings of others. Of interest and apparently inexplicable for the author are the higher scores of the recidivists when compared to first-termers. Maybe the intelligence is here manifest by the ability to get a short prison sentence or an early release from prison. Although the statistical presentation of the results is not of the best, these findings certainly do not reinforce the position of those that believe that education can

eliminate crime or that criminals are all feeble-minded.

MIND EXPLORERS.

By John K. Winkler and Walter Bromberg. Reynal and Hitchcock, New York. $3.00. 8½ x 5¾; [4] + 378; 1939.

The development of psychology as a science, and of psychiatry, from the 18th century when interest in human nature first became widespread and objective to the present day, is presented in this book in a series of excellent biographic sketches of the investigators whose contributions and influence have been most significant. With a chapter each devoted to the more dramatic Gall and Mesmer, it is to be regretted that the brilliant treatises of the still earlier students, Locke, Hume, and Bentham are not mentioned. However, the names selected provide a comprehensive survey of important advances on many fronts: Pinel, Eli Todd, Charcot, Francis Galton, William James, Stanley Hall, Cattell, Terman, Yerkes, Thorndike, Lashley, Watson, Freud, Adolf Meyer, and Clifford Beers. The contributions of each of these men as a logical outcome of his own personality and experience makes fascinating reading, and the interlocking of influence from man to man and country to country welds the mass of information into an intelligible historical whole. The book gives a clear, critically well-evaluated formulation of the genetic-dynamic development of the rapidly expanding sciences of human personality function. There is a short, well-selected list of important references.

THE MIND OF THE BEES.

By Julien Françon. Translated by H. Eltringham. Methuen and Co., London. 6s. net. 7¾ x 5¼; xi + 146; 1939.

Most of the studies on insect behavior have been confined to the laboratory where conditions are likely to be just about as unnatural as possible. This, however, is not the case in this excellent study of bees by M. Françon. Many years of field observation and ingenious experimentation in nature have convinced the author that the bees have a remarkable ability to communicate to one another precise directions as to the position and availability of certain materials valuable for the production of honey. M. Françon also believes that the economy of the hive is such that extra workers may be regimented at a moment's notice when the value of the "find" seems to warrant it, and that the number of extras put on the job is accurately proportioned in relation to the distance from the hive, and the quality of such a "find".

The book is clearly and simply written. It will be read with great interest, not only by bee-keepers, but also by entomologists in general whose interests lie in the field of animal behavior.

THE LIFE AND DEATH INSTINCTS (*The Vita and the Fatum*).

By Arthur N. Foxe. The Monograph Editions, 25 West 54th St., New York. $2.00. 8 x 5½; 64; 1939.

In this rambling, verbose little volume, Dr. Foxe purports to offer a psychoanalytic examination of the vita and the fatum. At least three etiological factors are alleged to be involved in the formation of the criminoses:—a severe trauma sustained in infancy or early childhood, a real want or need that cannot be satisfied in the home, and the hidden participation of other members of the family in the criminotic behavior. The author also expresses himself concerning chance and determinism, war and peace, transference and recognizance, and the interplay of the vita, the libido, and the fatum. There is a bibliography, but no index.

DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

MODERN SCIENCE. *A Study of Physical Science in the World Today.*

By Hyman Levy. Diagrams by Joan Samuell. Alfred A. Knopf, New York. $5.00. 9½ x 6¼; x + 736; 1939.

Within the last 15 years a succession of books has appeared, each, as Prof. Levy points out, more startling than the previous, in which science is presented in mysterious garb. This has been to invert its true purpose. If science means anything it entails clearing the atmosphere by reducing it to reason and finally it and common sense to a common denominator. This volume has been written "to present a balanced picture of the whole . . . [and] to attempt to picture the goal towards which the present crisis is converging."

An understanding of the scheme of the book is important. Part I, The energy of man, discusses the background of social life within which science has developed.

"Today the ferment among scientific men is stimulated by the same disillusionment as urged on the Encyclopaedists; historically, however, it must be seen as the next stage of the ferment of the seventeeth century in this country [England]. It is disillusionment *after* the Industrial Revolution; it is the drive to advance science beyond the mere study of nature at the level of inanimate matter, to the level of men in their group activity." The new division of the British Association "to explore the social relations of science is a step in the rational process of paving the way to the new society."

Part II deals with the coming of the machine and attempts to explain and clarify the general ideas which were the outgrowths of this phase. "It shows how the mind of man was affected in its thinking by the machine he was creating."

Part III discusses "groups or systems of things, ideas, events that can be made to show a pattern or an orderliness in their arrangements." It treats of the historical development and use of numbers, and "the struggle for mental freedom and expression in mathematical form." This section, which concludes with The language and measurement of movement:—the calculcus, and problems of the calculus, will have special significance for the mathematician. The headings of the last four parts are: Newtonian laws; The perfection of shape [one of the chapter headings of this section is Shaking off the past.—The sad story of Euclidean geometry]; What is the universe?; and The age of light; with an epilogue, Science in travail.

One hundred and fifty-four diagrams aid in clarifying the text. The volume is not documented but has an adequate index.

A Short History of Science.
By W. T. Sedgwick and H. W. Tyler. Revised by H. W. Tyler and R. P. Bigelow. The Macmillan Co., New York. $3.75. 8½ x 5½; xxi + 512 + 9 plates; 1939.

This text, intended for a beginner's course in the history of science, embodies the development of scientific thought from the time of the earliest recording of ideas down to about the end of the nineteenth century. To include such a vast amount of history in one volume is an enormous task, and the discussion of any particular phase of science must of necessity be very brief. The progression of events in the physical sciences, and particularly mathematics, is somewhat more detailed than that of the natural sciences.

The writers state specifically that there is no attempt at completeness. This fact is most severely felt in that the progression of scientific ideas and discoveries is not correlated with the progression of other historical happenings. This lack of correlation in the textual material is, however, somewhat compensated by the chronological listing of some important dates, names, and events in Appendix B. Appendices A and C list, respectively, some inventions of the eighteenth and nineteenth centuries, and a small number of reference books in the history of science.

The volume is generously illustrated and comprehensively indexed.

Science Today and Tomorrow.
By Waldemar Kaempffert. The Viking Press, New York. $2.50. 8⅛ x 5¼; 275; 1939.

The advance of science up to the present day, and its possibilities for the future are clearly presented for the lay reader of this volume. The early chapters discuss the solar system, the question of its

origin, and the possibility of interplanetary travel. Next the problem of power is considered. When the world's supply of coal is exhausted will we use tides, wind, sunlight? Kaempffert goes on to consider whether or not the laboratory can create life, the advances of genetics, and Carrel's work in tissue culture. Finally the rapid advances in the physical sciences are discussed and the relation of science to democracy. It is his belief that totalitarianism denies the liberty of mind which is necessary to objective research, and that in science we have the savior of democracy and the nidus of internationalism.

This book is adjusted to the understanding of the general public. Some more critical scientific minds may not rate it highly.

SCIENCE SINCE 1500. *A Short History of Mathematics, Physics, Chemistry, Biology. Board of Education, Science Museum.*

By H. T. Pledge. H. M. Stationery Office, London; British Library of Information, New York. $2.15. 9¾ x 6; 357 + 16 plates; 1939.

This text, a history of mathematics, physics, chemistry, and biology, is a panoramic survey of these sciences from 1500 to recent years. The study is set against a background of human and economic factors in the successive periods. Biography, as a detailed study, has been suppressed, but enough has been given to counterbalance the monotonous effect of the exposition of so many scientific discoveries, theories, and experiments. Particularly interesting is the author's treatment of the microscope in science. Maps showing how the birth-places of scientists seem to cluster about certain geographical locations in particular periods and times and charts showing teacher-pupil relationships for the 16th to 19th centuries form a very interesting piece of work. The latter relationships show how a number of noted scientists fall into a continuous teacher-pupil line; this linkage holds for the experimental and biological sciences rather than for the mathematical—mathematicians seeming to learn from texts, not persons. There are full-page photographs, facsimiles, text drawings, and graphs.

HANDBOOK OF PHOTOGRAPHY.

Edited by Keith Henney and Beverly Dudley. Whittlesey House, McGraw-Hill Book Co., New York and London. $7.50. 9 x 6; xii + 871; 1939.

The editors of *Photo Technique* have produced a book of great value to the photographer—whether he be specialist or amateur. It comes as near being the photographer's *Vade Mecum* as anything that has so far appeared in print. The 23 contributors (30 sections) have arranged their material in such a way that it is quickly available to the reader. However, it must be said that if the very excellent indexes (author and subject) were lacking this would not be the case, since the subject matter is arranged under topics—with full discussions to make all points clear. Perhaps a *Vade Mecum* is the next stage in development, with this book a valuable and necessary accompaniment. We are unable in the brief space allotted to include a list of the writers but they have been chosen for their outstanding accomplishments in their particular fields. A random sampling of the topics discussed yields the following: optics of photographic lenses, cameras, shutters, photographic sensitometry, photographic light sources, light filters, technique of development, defects in negatives, stereoscopic photography, infrared and ultraviolet photography, color photography, motion picture photography, aerial photography, high-speed photography, photomicrography, and radiography. Tables, graphs, figures and bibliographies enrich the various sections and in a group of appendices additional material not available in the body of the book is arranged.

PICTURES WITH A PURPOSE, HOW THEY ARE MADE.

By Charles Kerlee. Camera Craft Publishing Co., San Francisco. $2.50. 10 x 8¼; 80; 1939 (paper).

This slight volume consists of 24 "pictures with a purpose" or commercial photographs. Each reproduction, and each is very fine of its type, is accompanied by two pages of text in which the author discusses the particular purpose of the picture in question, the main points to be brought out to accomplish this purpose and the various technicalities employed for best results. This work should be of great interest to amateur photographers who hope to turn their hobby to profit.